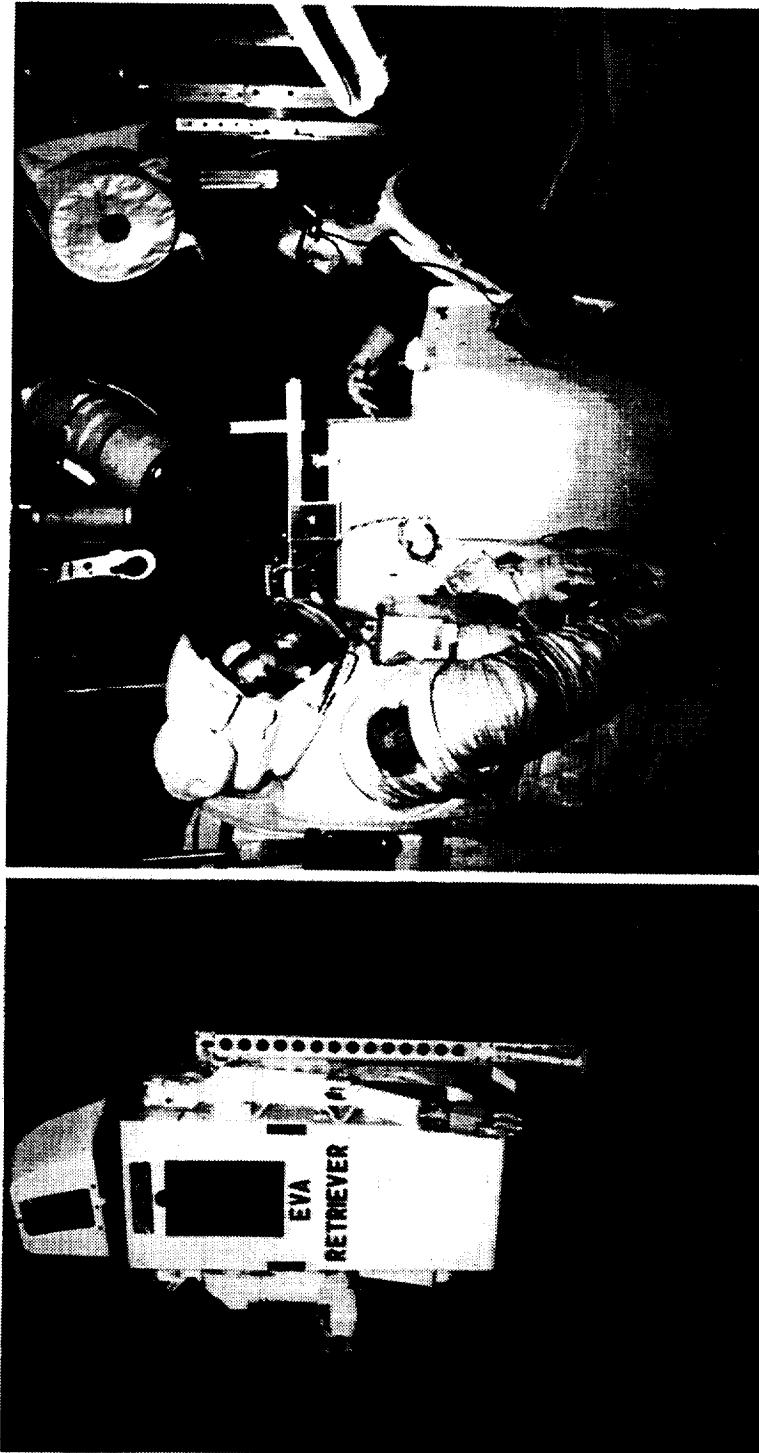


NASA-TM-109895

JSC-19295  
Revised 01/93

# Engineering Directorate

# TECHNICAL FACILITIES CATALOG



NASA

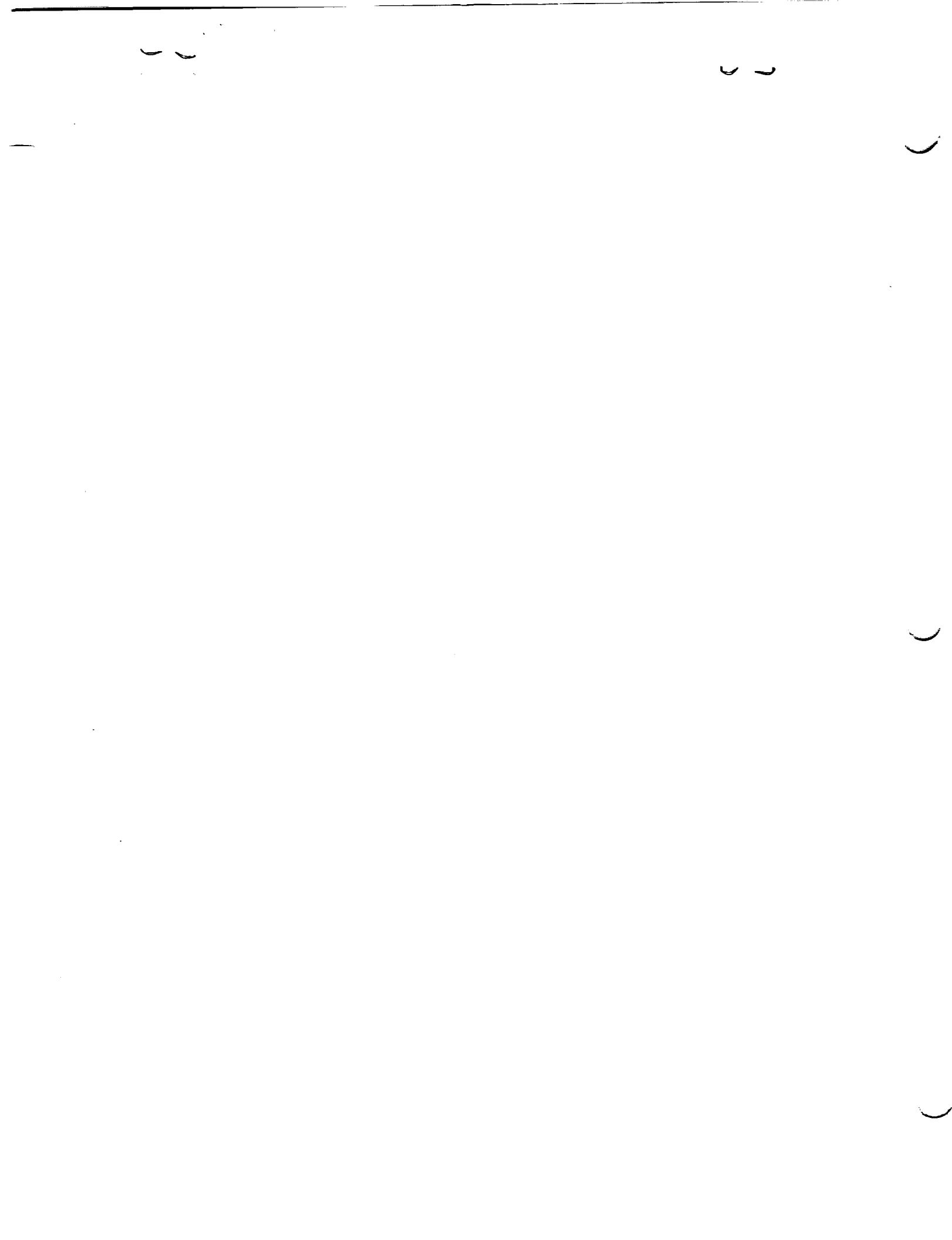
Lyndon B. Johnson Space Center  
Houston, Texas 77058

(NASA-TM-109895) ENGINEERING  
DIRECTORATE TECHNICAL FACILITIES  
CATALOG (NASA-Johnson Space  
Center) 331 p

N94-37443

Unclass

63/09 0019893

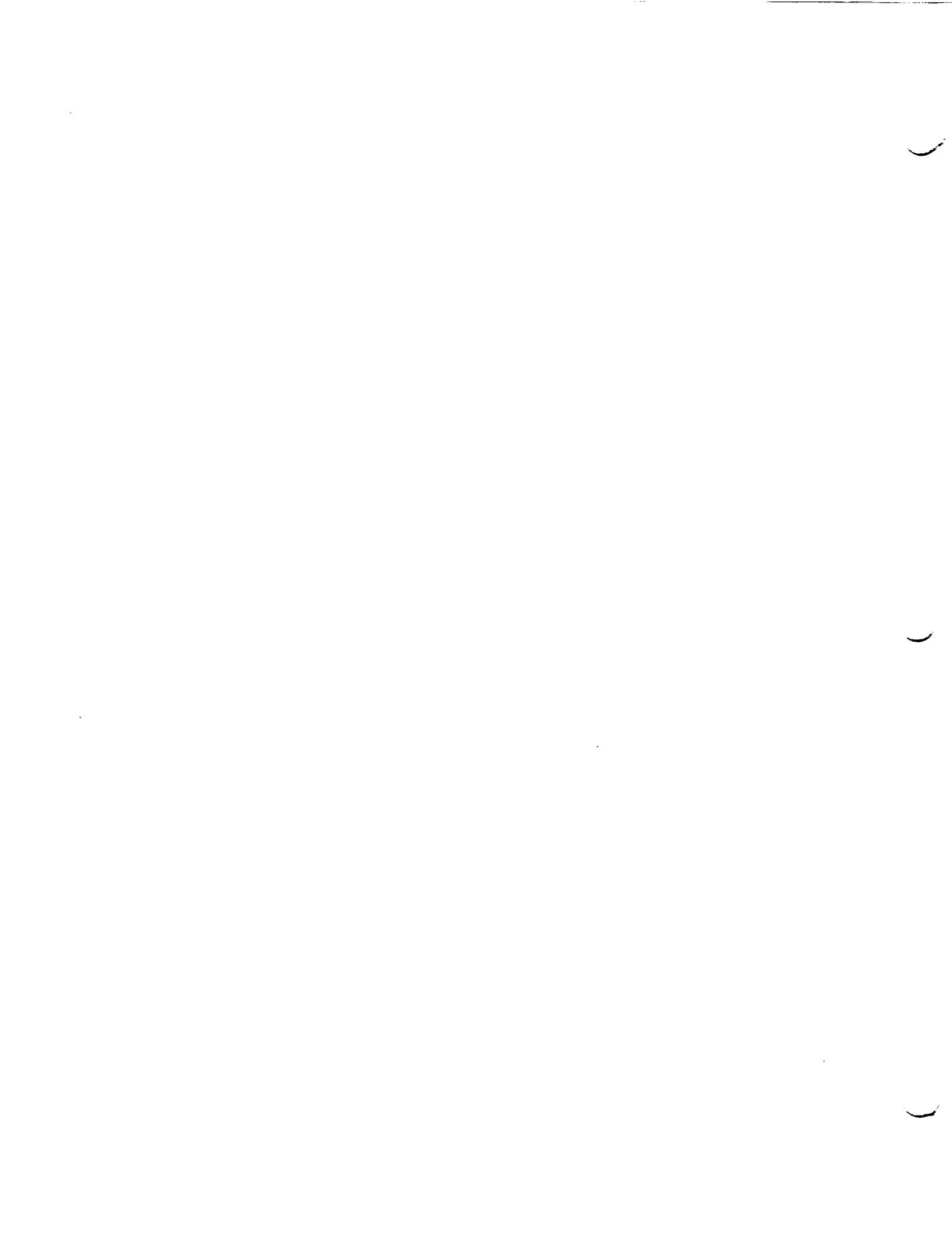


# ENGINEERING DIRECTORATE TECHNICAL FACILITIES CATALOG

Prepared By  
Management Support Office  
Engineering Directorate

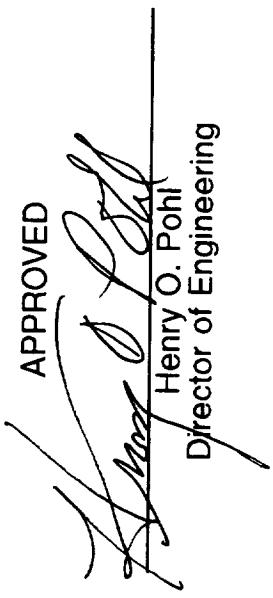
National Aeronautics and Space Administration  
Lyndon B. Johnson Space Center  
Houston, Texas 77058

Revised January 1993



ENGINEERING DIRECTORATE  
TECHNICAL FACILITIES CATALOG

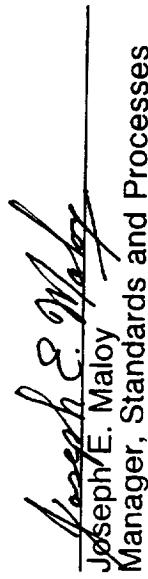
APPROVED

  
Henry O. Pohl  
Director of Engineering

CONCURRENCE

  
Robert D. Schwartz  
Manager, Management Support Office

PREPARER

  
Joseph E. Maloy  
Manager, Standards and Processes

Prepared By

Management Support Office  
Engineering Directorate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS

January 1993



## Preface

The Engineering Directorate Technical Facilities Catalog is designed to provide an overview of the technical facilities available within the Engineering Directorate at the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center (JSC) in Houston, Texas. The combined capabilities of these engineering facilities are essential elements of overall JSC capabilities required to manage and perform major NASA engineering programs.

The facilities are grouped in the text by chapter according to the JSC division responsible for operation of the facility. This catalog updates the facility descriptions for the JSC Engineering Directorate Technical Facilities Catalog, JSC 19295 (August 1989), and supersedes the Engineering Directorate,

Principle Test and Development Facilities, JSC 19962  
(November 1984).

This catalog provides two means of locating information of interest. The Table of Contents lists the facilities by division; the appendix lists the same facilities by JSC building number with a cross reference to the responsible organization. The building location can be determined by locating the building number on the JSC site map.

Within each section of the catalog, the text description of each facility also identifies the number of the JSC building where that particular facility is housed.

PAGE BLANK NOT FILMED



## Contents

CHAPTER	TITLE	PAGE	CHAPTER	TITLE	PAGE
1	CREW AND THERMAL SYSTEMS DIVISION (EC)	1-1		Hybrid Regenerative Wastewater Recovery Laboratory	1-72
	Advanced Life Support Systems Development and Test Complex	1-2		Regenerative Life Support System Test Bed (Variable Pressure Growth Chamber, Ambient Pressure Growth Chamber)	1-73
	Advanced EVA Mobility Unit Development Laboratory	1-10			
	Chamber A High Vacuum/Thermal Man-Rated Test Complex	1-12	2	TRACKING AND COMMUNICATIONS DIVISION (EE)	2-1
	Chamber B High Vacuum/Thermal Man-Rated with Solar Test Complex	1-19		Advanced Audio Development Laboratory	2-2
	Chamber Operations, Lock Observers, and Personnel Equipment Shop	1-24		Advanced Voice Processing Laboratory	2-4
	Chemistry Laboratories	1-25		Anechoic Chamber Facility	2-5
	Advanced Materials Laboratory	1-26		Communication Systems Development Laboratory	2-9
	Data Acquisition, Recording, Display, and Computer Complex	1-27		Communication Systems Simulation Laboratory	2-11
	Eight-Foot (2.4 Meter) Chamber Life Support Systems Canned-Man Test Complex	1-29		Communications Software Development Laboratory	2-16
	Electrical Fabrication, Electronic, and Instrumentation Shops	1-32		Electrical-Acoustical Laboratory	2-21
	Eleven-Foot (3.4 Meter) Chamber Manned Test Complex	1-33		Electromagnetic Compatibility and Electromagnetic Interference Testing Laboratory	2-23
	Heat Pipe and Thermal Test Complex	1-37		Electronic Systems Test Laboratory	2-26
	Impact Test Facility	1-39		Flight Equipment Assembly Area	2-34
	Instrumentation Calibration and Electronic Repair Laboratory	1-41		Global Positioning System (GPS) Laboratory	2-35
	Mechanical Shops	1-42		Government-Furnished Equipment Flight Hardware Development and Processing Facility	2-37
	Shuttle Thermal and ETA Test and Man-Rated Training Complex	1-43		High-Temperature Superconductivity Laboratory	2-39
	Soft Goods Fabrication Laboratory	1-47		Hybrid Vision Laboratory	2-41
	Special Chambers Complex	1-49		Image-Based Tracking Laboratory	2-44
				Microwave Design Laboratory	2-46
				Microwave Integrated Circuit Facility	2-49
				Optical Tracking and Communications Laboratory	2-52

~~PREVIOUS PAGE BLANK NOT FILMED~~

CHAPTER	TITLE	PAGE	CHAPTER	TITLE	PAGE	CHAPTER	TITLE	PAGE
	Outdoor Antenna Range Facility .....	2-55		Real-Time Systems Engineering Laboratory .....	4-36		Real-Time Systems Engineering Laboratory .....	4-36
	Precision Six-Degrees-of-Freedom Test Facility .....	2-57		Space Station 1553 Local Bus Test Bench .....	4-39		Space Station 1553 Local Bus Test Bench .....	4-39
	Radar Boresight Facility .....	2-60		Time Generation System Testbed .....	4-41		Time Generation System Testbed .....	4-41
	Radar Laboratory .....	2-63		Multiplexer/Demultiplexer and Orbiter Data Bus Test Laboratory .....	4-43		Multiplexer/Demultiplexer and Orbiter Data Bus Test Laboratory .....	4-43
	Signal Processing Laboratory .....	2-65		Computing Facility .....	4-45		Computing Facility .....	4-45
	Television Systems Laboratory .....	2-69						
	Text and Graphics Laboratory .....	2-73		5 PROPULSION AND POWER DIVISION (EP) .....	5-1		5 PROPULSION AND POWER DIVISION (EP) .....	5-1
	Video Cassette Recorder System Laboratory .....	2-76		Electrical Power Systems Laboratory .....	5-2		Electrical Power Systems Laboratory .....	5-2
				Thermochemical Test Area .....	5-4		Thermochemical Test Area .....	5-4
3	NAVIGATION CONTROL AND AERONAUTICS DIVISION (EG) .....	3-1		Thermal Vacuum Test Facility .....	5-6		Thermal Vacuum Test Facility .....	5-6
	Electro-Optics Laboratory and Rooftop Tracking Laboratory .....	3-2		Pyrotechnics Test Facility .....	5-10		Pyrotechnics Test Facility .....	5-10
	Inertial Components Laboratory .....	3-6		Propulsion Test Facility .....	5-14		Propulsion Test Facility .....	5-14
	Inertial Systems Laboratory .....	3-9		Power Systems Test Facility .....	5-19		Power Systems Test Facility .....	5-19
				Fluid Systems Test Facility .....	5-24		Fluid Systems Test Facility .....	5-24
4	FLIGHT DATA SYSTEMS DIVISION (EK) .....	4-1		6 AUTOMATION AND ROBOTICS DIVISION (ER) .....	6-1		6 AUTOMATION AND ROBOTICS DIVISION (ER) .....	6-1
	Shuttle Avionics Integration Laboratory .....	4-2		Laboratory Support .....	6-3		Laboratory Support .....	6-3
	JSC Avionics Engineering Laboratory .....	4-9		Intelligent Systems Laboratory .....	6-5		Intelligent Systems Laboratory .....	6-5
	Modular Auxiliary Data System Instrumentation Laboratory .....	4-14		Integrated Graphics Operations and Analysis Laboratory .....	6-7		Integrated Graphics Operations and Analysis Laboratory .....	6-7
	Software Development Facility .....	4-17		Robotic Systems Evaluation Laboratory .....	6-9		Robotic Systems Evaluation Laboratory .....	6-9
	Microprocessor Laboratory .....	4-20		Dexterous Robotics Laboratory .....	6-10		Dexterous Robotics Laboratory .....	6-10
	Flight Tape Recorder Laboratory .....	4-24		Mobile Robotics Laboratory .....	6-12		Mobile Robotics Laboratory .....	6-12
	Instrumentation Laboratory .....	4-27		Telepresence Laboratory .....	6-13		Telepresence Laboratory .....	6-13
	Displays and Controls Laboratory .....	4-32		Robotic Sensor Integration Laboratory .....	6-14		Robotic Sensor Integration Laboratory .....	6-14
				Space Systems Automated Integration and Assembly Facility .....	6-15		Space Systems Automated Integration and Assembly Facility .....	6-15

CHAPTER	TITLE	PAGE	CHAPTER	TITLE	PAGE	PAGE	TITLE
	Manipulator Development Facility .....	6-17		Small Radiant Heating Test Facility .....	7-38		
	Electronics Development Laboratory .....	6-18		Structures Test Laboratory .....	7-39		
	Vibration and Acoustic Test Facility .....			General Vibration Laboratory .....	7-44		
7	<b>STRUCTURES AND MECHANICS DIVISION (ES)</b> .....	7-1		Modal Operations Laboratory .....	7-47		
	Atmospheric Reentry Materials and Structures Evaluation Facility .....	7-2		Spacecraft Acoustic Laboratory .....	7-49		
	Materials Technology Laboratory .....	7-6		Sonic Fatigue Laboratory .....	7-51		
	Atomic Oxygen Facility .....	7-8		Spacecraft Vibration Laboratory .....	7-53		
	Chemical Analysis Laboratory .....	7-10			7-55		
	Electron Microscopy Laboratory .....	7-13	8	<b>SYSTEMS ENGINEERING DIVISION (ET)</b> .....	8-1		
	Mechanical and Physical Testing Laboratory .....	7-16		Systems Engineering Simulator Image Generators and Display Systems .....	8-2		
	Metallurgical Laboratory .....	7-19		Systems Engineering Simulator Shuttle Ascent/Entry/Abort Simulation .....	8-3		
	Nondestructive Testing Laboratory .....	7-22		Systems Engineering Simulator On-Orbit Elements .....	8-4		
	Optical Analysis Laboratory .....	7-25		Systems Engineering Division Computer Laboratory .....	8-6		
	Rubber Laboratory .....	7-26					
	Thermal Analysis Laboratory .....	7-28					
	Radiant Heating Test Facility .....	7-31					
	Electro-Mechanical Systems Laboratory .....	7-35		APPENDIX: LIST OF FACILITIES BY BUILDING NUMBER .....	A-1		

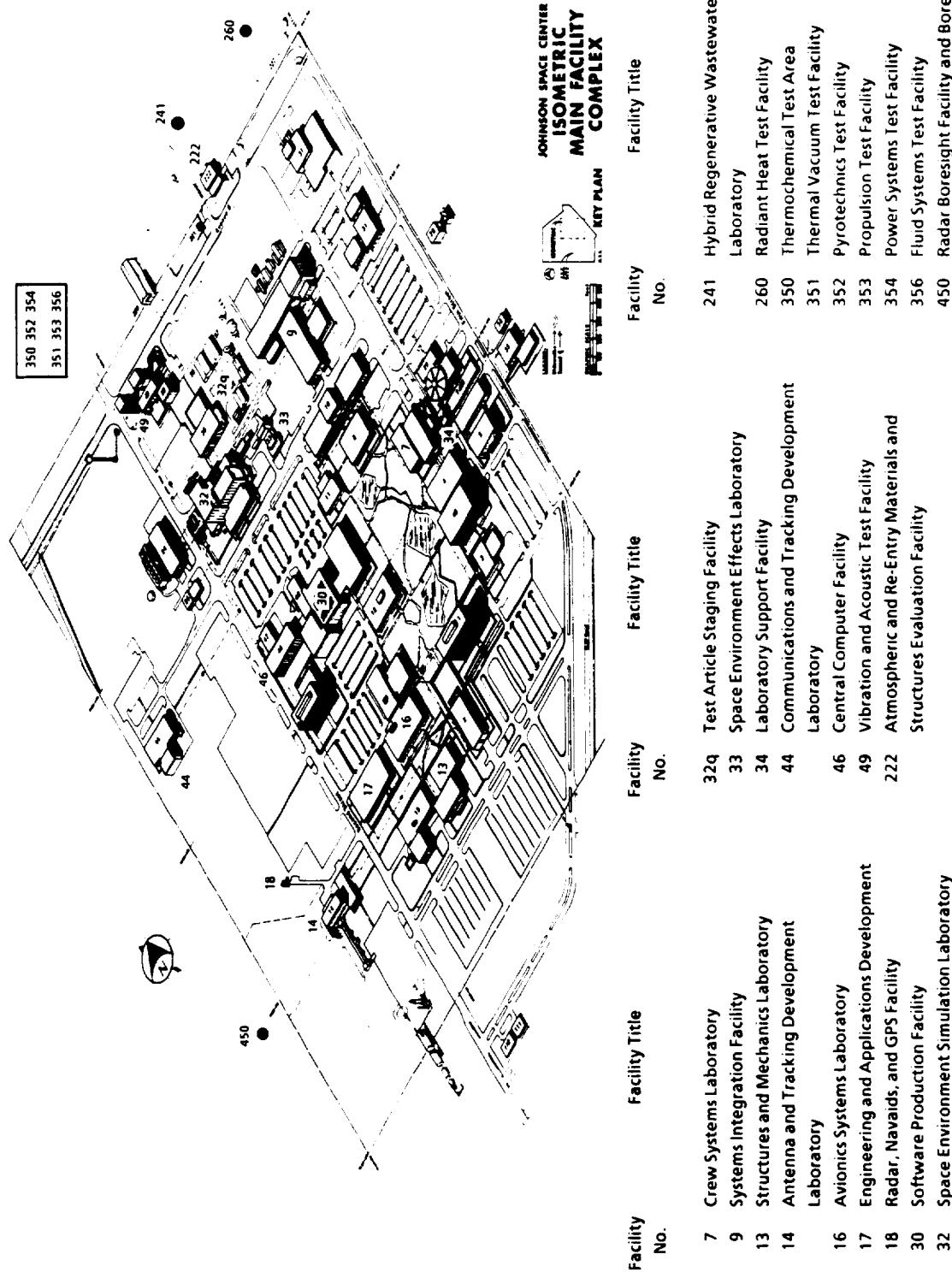


## Acronyms

ETA	Environmental Test Article
EVA	ExtraVehicular Activity
GPS	Global Positioning System
IBM	International Business Machines
IEEE	Institute of Electrical and Electronic Engineers
JSC	Johnson Space Center
NASA	National Aeronautics and Space Administration
SSE	Space Station Software Support Environment
STS	Space Transportation System
VAX	Virtual Addressing eXtended



## MAP OF JSC FACILITIES





## Chapter 1

### CREW AND THERMAL SYSTEMS DIVISION (EC)

#### **Contents**

<b>FACILITY</b>	<b>PAGE</b>	
Advanced Life Support Systems Development and Test Complex	1-2	Soft Goods Fabrication Laboratory .....
Advanced EVA Mobility Unit Development Laboratory	1-10	Special Chambers Complex .....
Chamber A High Vacuum/Thermal Man-Rated Test Complex	1-12	Hybrid Regenerative Wastewater Recovery Laboratory .....
Chamber B High Vacuum/Thermal Man-Rated with Solar Test Complex	1-19	Regenerative Life Support System Test Bed (Variable Pressure Growth Chamber, Ambient Pressure Growth Chamber) .....
Chamber Operations, Lock Observers, and Personnel Equipment Shops	1-24	
Chemistry Laboratories	1-25	The Crew and Thermal Systems Division designs, tests, and analyzes life support systems, environmental control systems, and active thermal control systems for spacecraft and extravehicular activity (EVA) crew members. The division develops technology for these systems. It also is responsible for the design and development of crew equipment for EVA and other hazardous environments.
Advanced Materials Laboratory	1-26	
Data Acquisition, Recording, Display, and Computer Complex	1-27	
Eight-Foot (2.4 Meter) Chamber Life Support Systems Canned-Man Test Complex	1-29	The EC Division provides manned and unmanned test capability in both vacuum and thermal-vacuum environments.
Electrical Fabrication, Electronic, and Instrumentation Shops	1-32	
Eleven-Foot (3.4 Meter) Chamber Manned Test Complex	1-33	In-house capability exists for softgoods fabrication, nonmetallic materials development and testing, wet and gas chemical analysis, and EVA and payload mechanical equipment design.
Heat Pipe and Thermal Test Complex	1-37	
Impact Test Facility	1-39	
Instrumentation Calibration and Electronic Repair Laboratory	1-41	
Mechanical Shops	1-42	In addition, expert systems, artificial intelligence, and robotics are applied to the subsystem and system areas within the EC Division's purview as appropriate.
Shuttle Thermal and EVA Test and Man-Rated Training Complex	1-43	

## General Facility Specifications

### ADVANCED LIFE SUPPORT SYSTEMS DEVELOPMENT AND TEST COMPLEX

LOCATION: Building 7, High Bay and Rooms 2004, 2005, 2006, and 2007

Building 7 and the man-rated, twenty-foot (6.1-meter) chamber, including the control and pump rooms.

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4, (713) 483-9208

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$600k

REPLACEMENT COST: \$5,043k

USE: Chambers in the Advanced Life Support Systems Development and Test Complex are used to simulate crew compartment volumes of representative future human habitats for environmental control systems testing. The test facilities are used to support the checkout and repair of environmental and regenerative life support systems on three testing levels: component, individual subsystems, and integrated subsystems into various system level tests.

DESCRIPTION: This test complex is comprised of several areas in Building 7, each designed with a unique capability essential to testing and certifying the specialized equipment necessary for water reclamation or air revitalization. These areas are the laboratories in Rooms 2005, 2006, and 2007 of

The laboratories support three major types of test activity. Rooms 2005 and 2006 are designed to perform long-life, unattended, continuous testing of each individual subsystem for both water reclamation and air revitalization groups. Room 2007 can be used to perform acceptance and checkout testing of singular systems both in normal operating mode and in worst case conditions. In addition, total integrated testing can be accomplished on both groups of equipment functioning as a unit.

Test support utilities for Rooms 2004, 2005, 2006, and 2007 are presented in tables on the following pages.

The man-rated, twenty-foot (6.1-meter) chamber is a stainless-steel cylinder approximately 6.7 meters high. The top of the chamber is removable. An aluminum diaphragm, with two man hatches and one equipment hatch, is located approximately .3 meter above the separation line. This diaphragm divides the main chamber into two approximately equal volumes of 278.7 square meters each. A 3.05-meter-diameter, two-compartment airlock, 6.1 meters long, is attached to the main chamber. The outer airlock is joined by a 1.98-cubic-meter, rapid decompression chamber. The main chamber may be pumped down to a simulated altitude of 67 056 meters. Manned tests are controlled by chamber and lock operators, test monitors, medical monitors, and test conductors located at consoles in

the control room. The chamber may be rapidly recompressed at controlled rates in the event of a manned test system failure. A closed-circuit television system monitors all areas within the chamber and airlocks. An intercommunication system allows test subjects and test team members to communicate with each other during the test.

The twenty-foot (6.1-meter) chamber has recently been modified by the addition of a 2.3-meter spool section, with integral pressure sealing diaphragm, to create a test volume

representative of a future manned module. A three man capacity crewman metabolic simulator controls N<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, and humidity levels inside the chamber for test hardware metabolic loading. Future changes include upgrading the control room and installing prototype and commercial Regenerative Life Support System support systems for evaluation and testing.

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

## TEST SUPPORT UTILITIES – ROOMS 2004, 2005, 2006, AND 2007

Location	Utility	Capacity	Comments
Room 2005 & 2006	Vacuum	2.44 kg/hr water vapor @ 3 kPa	Automatically actuated redundant vacuum pump
	Chilled water	10 886 kg-nominal delivery temp .55 °C	Automatically actuated redundant vacuum pump
	Hydrogen gas	103 kPa	
	Mixed gas bank (N <sub>2</sub> & CO <sub>2</sub> )	103 kPa	
Room 2007	Chilled water	4536 kg-nominal delivery temp .55 °C	
	Hydrogen	103 kPa	
	Mixed gas bank (N <sub>2</sub> , CO <sub>2</sub> , & breathing air)	103 kPa	

**INDIVIDUAL COMPARTMENT INTERIOR DIMENSIONS AND CAPABILITIES FOR THE MAN-RATED,  
20-FOOT CHAMBER**

Compartment	Size	Volume	Ultimate vacuum	Pump type	Pump capacity
Main chamber	6 by 8.38 m high	229 m <sup>3</sup>	64 m <sup>-1</sup>	Root blowers	121.76 m <sup>3</sup> /min
Inner air lock	3 by 2.74 m long	21.5 m <sup>3</sup>	10.1 kPa	Nash	3.11 m <sup>3</sup> /min
Outer air lock	3 by 3 m long	23.36 m <sup>3</sup>	10.1 kPa	Nash	3.11 m <sup>3</sup> /min
Rapid decompression chamber	1.5 by 1.37 by .9 m	2.21 m <sup>3</sup>		Not applicable	

**CONTROL SYSTEM FOR THE MAN-RATED,  
20-FOOT CHAMBER**

Control type	Description
Electropneumatic	Manually actuated for normal operation; automatically actuated in emergency modes

## PUMP CAPACITY FOR THE MAN RATED, 20-FOOT CHAMBER

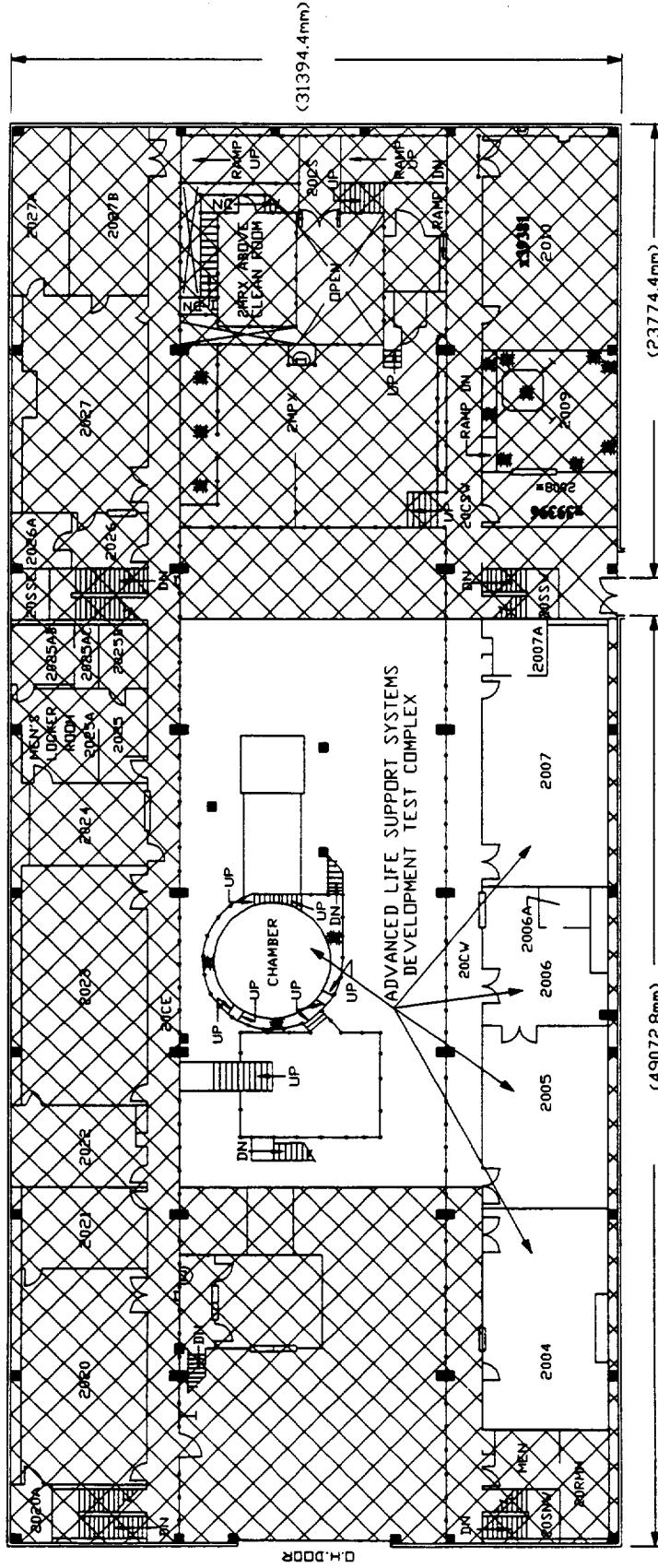
Pumps	Combined capacity	Combined ultimate altitude	Combined max. rate of climb to 1133 Pa
Roots-Connerville 25.4 cm by 41.9 cm blower	121.7 m <sup>3</sup> /min sea level to 133 Pa and 195 m <sup>3</sup> /min 133 Pa to max. vacuum	76 200 m (2.04 Pa)	76.2 m/s
Roots-Connerville 30.4 cm by 57.1 cm blower			
Beach-Russ RP-1000 rotary piston pump			

## MAXIMUM REPRESSURIZATION AND DECOMPRESSION RATES FOR THE MAN-RATED, 20-FOOT CHAMBER

Compartment	Pressure and altitude range	Maximum repressurization/decompression time
Total facility (main chamber and both air locks)	133 Pa to sea level 8229 m to sea level	14.0 sec 9.0 sec
Main chamber	133 Pa to sea level	10.2 sec
Main chamber and inner lock	8229 m to sea level	9.0 sec
Rapid decompression chamber	101 to 1 kPa 34 to 0.4 kPa	*
Outer lock	133 Pa to 5486 m 133 Pa to sea level	10.0 sec 26.0 sec

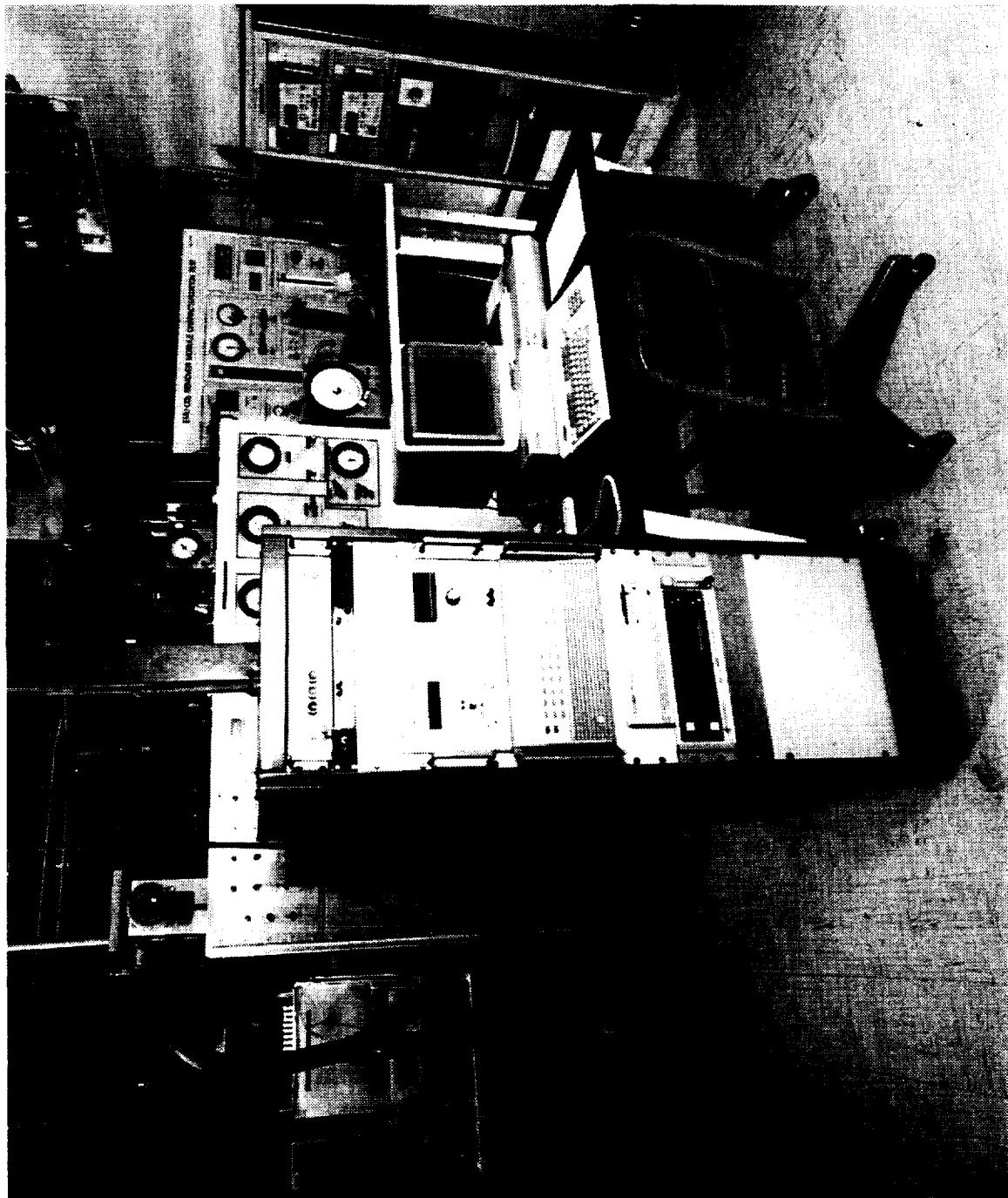
\*Maximum decompression time of 200 ms

JSC BUILDING 7 FLOOR PLAN, SECOND FLOOR



ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

ROOM 2007



MAN-RATED 20-FOOT CHAMBER



ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

## General Facility Specifications ADVANCED EVA MOBILITY UNIT DEVELOPMENT LABORATORY

LOCATION: Building 34

POINT OF CONTACT: Chief, EVA Branch, Code EC6,  
(713) 483-9254

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$310k

REPLACEMENT COST: \$1,815k

USE: The Advanced EVA Mobility Unit Laboratory provides the capability to conduct inhouse development activities, including mockup and prototype, fabrication and testing, and evaluation of proof-of-concept and new technology configurations of space suits and related components.

DESCRIPTION: The Advanced EVA Mobility Unit Laboratory provides the capability to fabricate and test space suit components and related hardware. The building is air-conditioned and has a second story loft. An overhead crane is available for lifting and moving hardware. Room 108 is used for space suit maintenance and checkout. Manned and unmanned suited tests are also conducted including fitchecks and component testing. Rooms 107 and 106 are component and materials storage areas. Room 105 is a softgoods and component fabrication area which includes sewing, cementing, and assembly. The high bay area includes machine tools for hardware fabrication. The loft area includes test equipment such as a curing oven, component torque measurement system, various component life endurance cycling systems, and a treadmill. A portion of the loft area includes helmet mounted display development equipment.

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

**ADVANCED EVA MOBILITY UNIT DEVELOPMENT LABORATORY**



S92-47272

## CHAMBER A HIGH VACUUM/THERMAL MAN-RATED TEST COMPLEX

### General Facility Specifications

LOCATION: Building 32, High Bay

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

STATUS: Active

YEAR BUILT: 1965

INITIAL COST: \$33,246k

REPLACEMENT COST: \$166,418k

USE: The Chamber A High Vacuum/Thermal Man-Rated Test Complex has capability to perform development and qualification testing of complete spacecraft or major subsystem hardware in high-fidelity simulated thermal vacuum space environments.

DESCRIPTION: Chamber A is the largest man-rated thermal vacuum chamber test complex at JSC. This chamber is located at the west side of the Building 32 High Bay. Chamber A shares major ancillary systems and supporting facility subsystems with Chamber B. The shared systems include the mechanical rough pumping, blower, and ventilation systems, as well as the west tank farm and cooling towers.

Chamber A is a man-rated, stainless-steel vacuum vessel 19.8 meters in diameter and 36.6 meters high. It provides a working

volume within a ninety degrees kelvin heat sink shroud of approximately 16.8 by 27.4 meters. The major structural elements of the chamber are the rotatable floor, the 12.2 meter (forty feet) diameter access door, the dual man locks at the floor level and at the 9.5 meter level, and the single access door at the 19.0 meter level. The chamber floor, which is 13.7 meters in diameter, can be rotated by manual control plus or minus 180 degrees about its vertical axis at continuously variable angular velocities up to a maximum of 0.8 revolutions per minute.

Test articles are normally inserted into the chamber by means of overhead cranes or mobile boom cranes. Two 45 400-kilogram cranes are used outside the chamber and four independently operated 22 700-kilogram cranes, lowered through removable sections of the top head, are used inside the chamber.

The dual man locks provide a potential for two test crew members to move from ambient air pressure to the thermal vacuum environment and back. They also provide for potentially maintaining rescue crew members at convenient intermediate pressures during manned test operations. When the inner door is bolted, either of the man locks can be used as an altitude chamber for independent tests.

The floor of the chamber on which test fixtures may be mounted will sustain a load of 90 800 kilograms and may be rotated during tests. The chamber floor can be cooled with liquid nitrogen and heated to 390 degrees kelvin. A system of mechanical

roughing pumps, twenty degrees kelvin cryopumps, and valved oil-diffusion pumps provides a pumping capacity of 1333 pascals per second for condensable gases and 39.9 pascals per second for noncondensable gases at a pressure of 1.33 by  $10^{-7}$  pascals. Usual chamber leakage of air is less than 1.06 by  $10^{-3}$  pascals per second. The time required to reach ultimate thermal vacuum pressure conditions is seven hours.

The space plasma simulation, a unique capability, is the result of a special configuration of this chamber. It establishes the capability to generate thermal plasma simulating the ionosphere in low Earth orbit. The configuration consists of a plasma generation system, magnetic confinement, and specialized plasma diagnostic instrumentation suitable to meet most user requirements. The large dimensions of this chamber permit quality ionospheric plasma simulations for large test articles.

#### General Characteristics

OUTSIDE DIMENSIONS: 19.8 meters in diameter by 36.6 meters high

WORKING DIMENSIONS: 16.8 meters in diameter by 27.4 meters high

TEST ARTICLE WEIGHT: 68 100 kilograms concentric load maximum

ACCESS: Side-hinged door, 12.2 meters in diameter; dual man locks at floor and 9.5 meter level; single access door at 19.0 meter level.

#### Vacuum Systems

TYPES OF PUMPS: Valved and trapped oil diffusion pumps and twenty degrees kelvin cryopumps

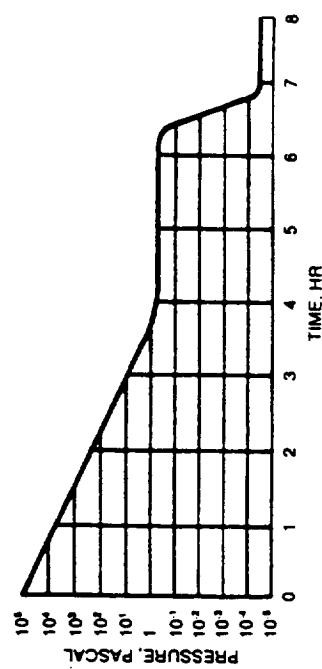
PUMPDOWN TIME: Seven hours to ultimate pressure

PUMPING CAPACITY: One by  $10^7$  liters per second condensables and three by  $10^5$  liters per second noncondensables at 1.33 by  $10^{-4}$  pascal pressure

NOTE: Usual chamber in-leakage is less than eight by  $10^6$  liters per second of air at 1.33 by  $10^{-4}$  pascal pressure

REPRESSURIZATION: Emergency is a ninety-second minimum; normal is controllable, with chamber dry out using dry gas purge and heated shroud and floor.

#### CHAMBER A PUMPDOWN CURVE



Heat Sink and Special Thermal Simulators

**FULL CHAMBER SHROUD:** Subcooled ninety degrees kelvin liquid nitrogen shroud with 330,000 watts total heat absorption capacity and 1393 watts per square meter maximum heat flux; can be heated to 312 degrees kelvin with gaseous nitrogen

**WALL EMISSIVITY:** 0.95

**SPECIAL SIMULATORS:** Albedo and planetary radiation, as required

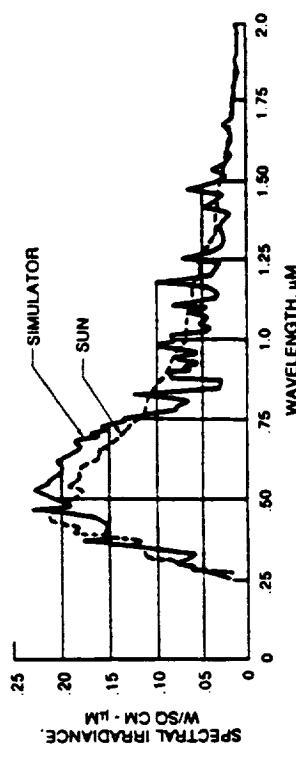
Solar Simulation

**SIDE SUN:** Thirty-seven xenon lamp modules for seventy-six potential array locations

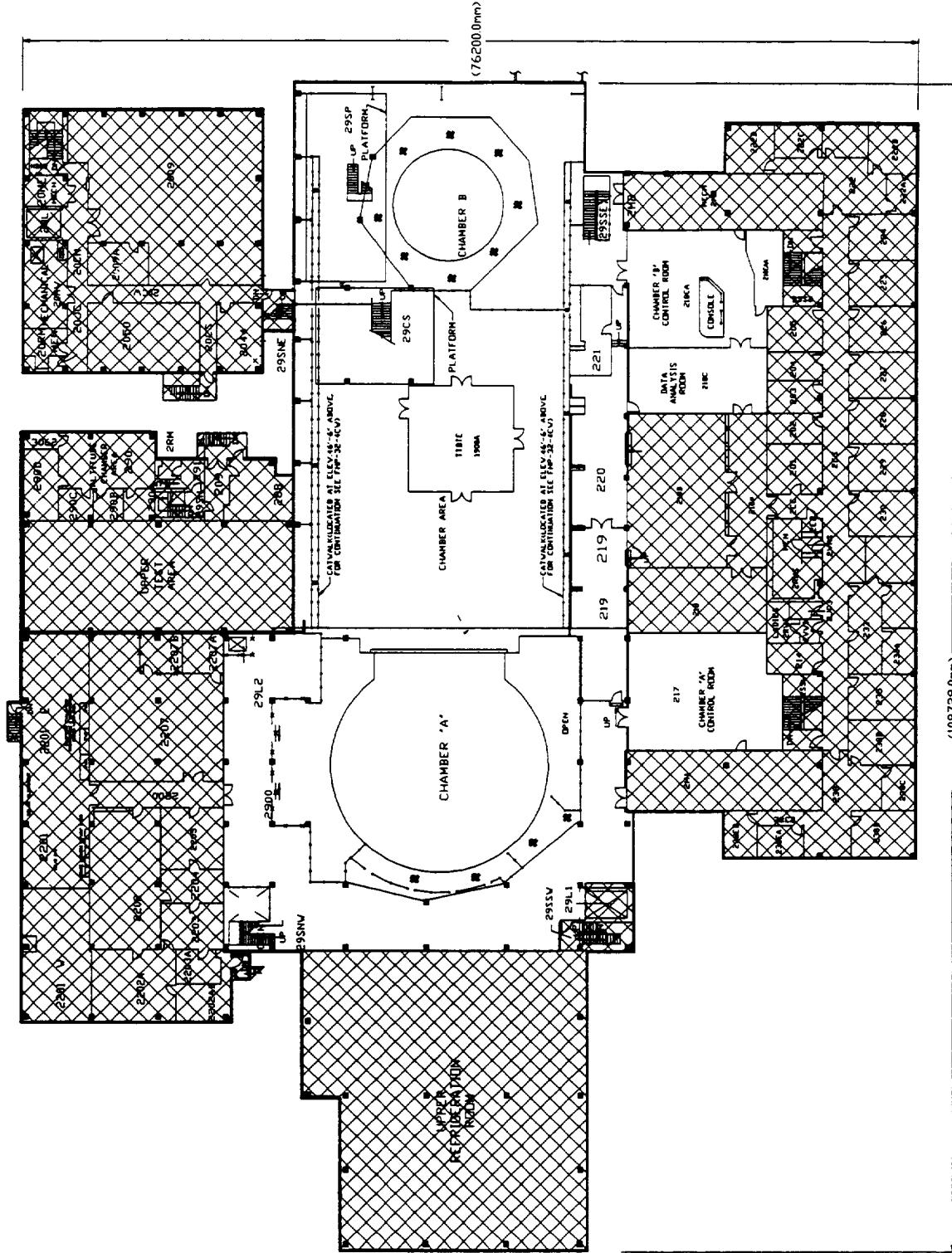
**DECOLLIMATION:** Ninety minute half angle

**INTENSITY:** 622 to 1353 watts per square meter (controllable)

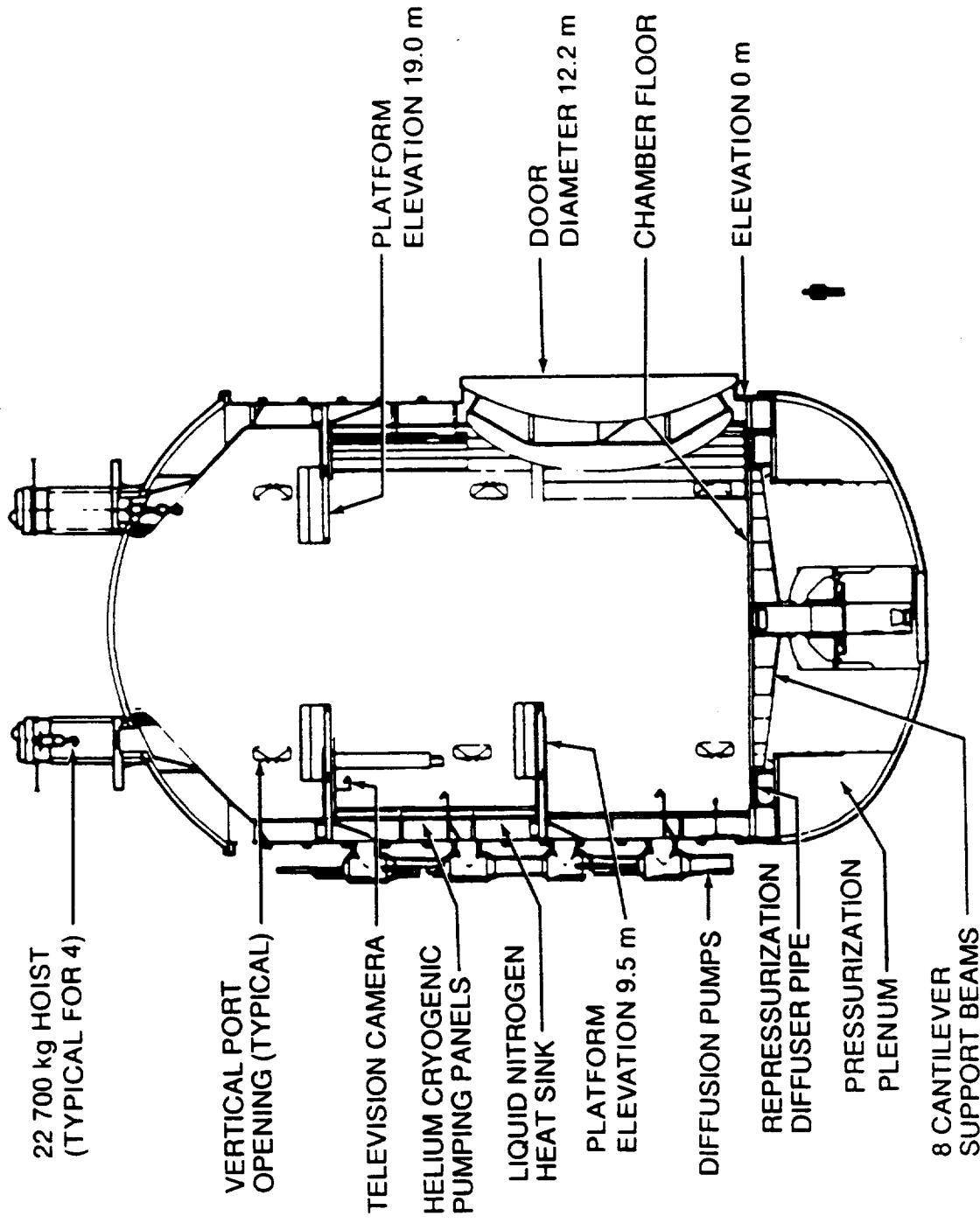
**DATA ACQUISITION:** Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.



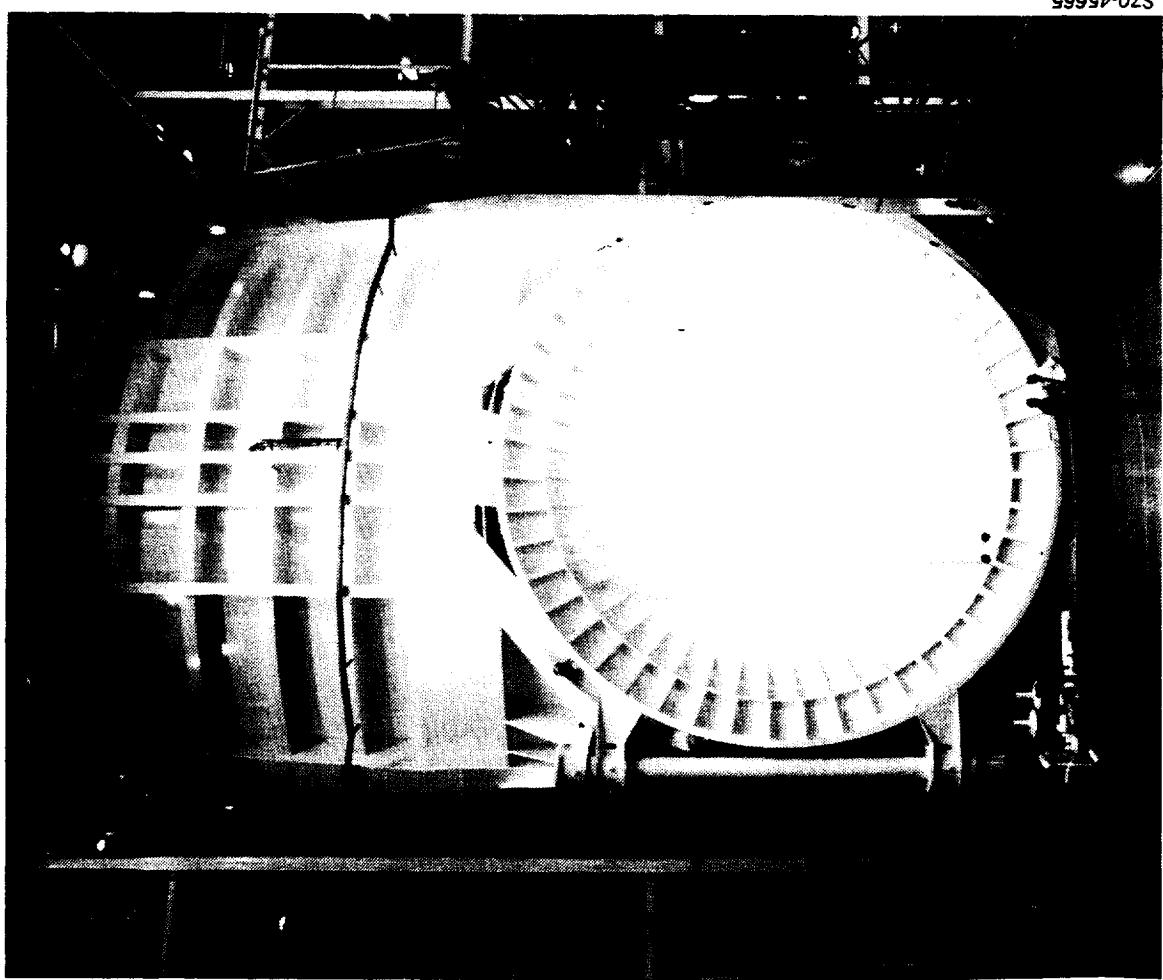
BUILDING 32 FLOOR PLAN



## CHAMBER A HIGH VACUUM/THERMAL MAN-RATED TEST COMPLEX



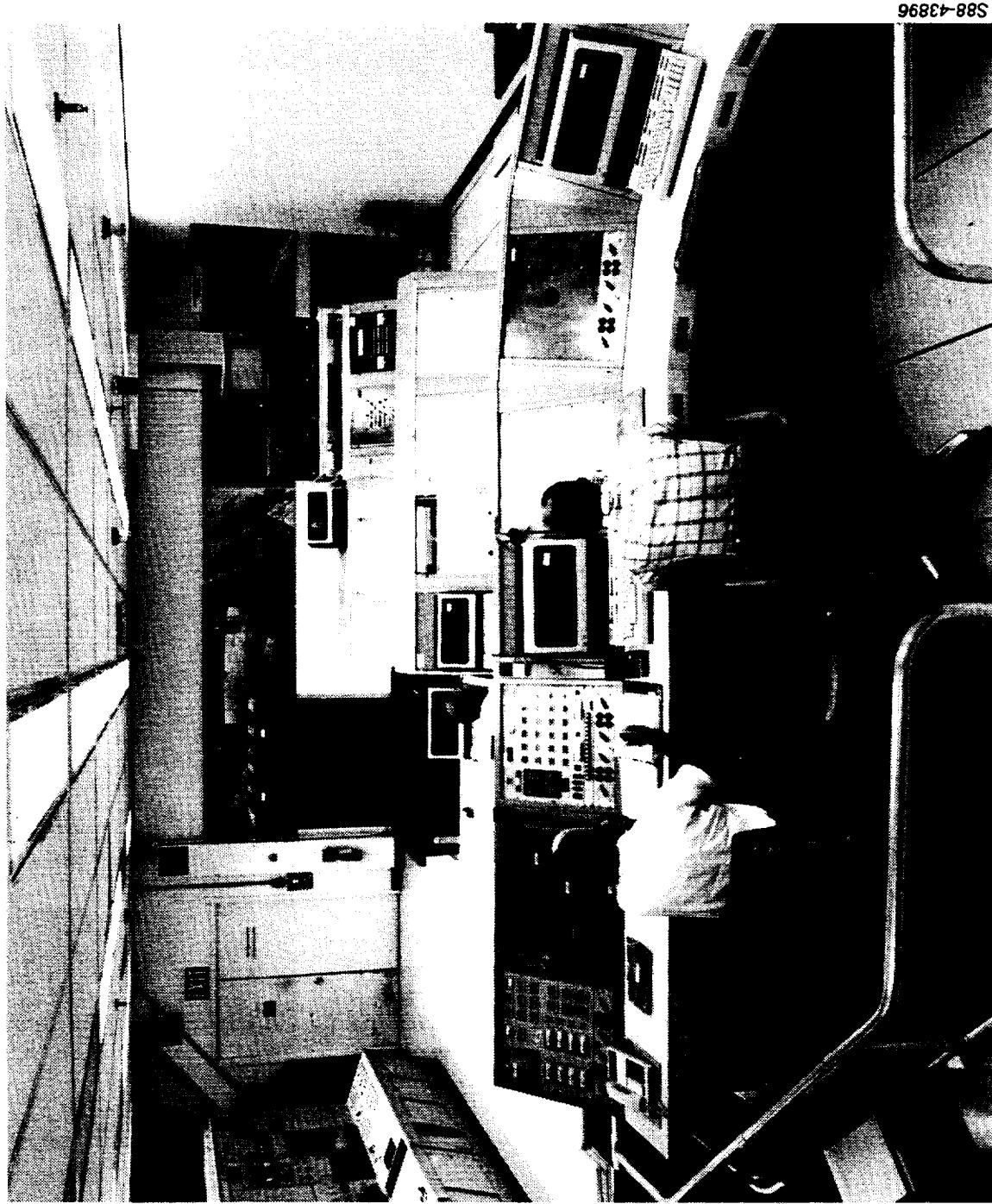
**CHAMBER A – HIGH VACUUM**



S70-45665

ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

TEST CONTROL AREA



## **General Facility Specifications**

### **CHAMBER B HIGH VACUUM/THERMAL MAN-RATED WITH SOLAR TEST COMPLEX**

**LOCATION:** Building 32, High Bay

**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** Not available

**REPLACEMENT COST:** \$79,079k

**USE:** The Chamber B High Vacuum/Thermal Man-Rated with Solar Test Complex has capability to perform manned and unmanned development and qualification testing of complete spacecraft or major subsystems hardware in high fidelity simulated thermal vacuum environments, including solar simulation and albedo.

**DESCRIPTION:** Chamber B is located in the east side of Building 32 High Bay. This man-rated chamber shares major ancillary systems and supporting facility subsystems with Chamber A. The systems shared are the mechanical rough pumping, blower, and ventilation systems, as well as the west tank farm and cooling towers. A single helium refrigeration skid is housed in a building located just east of Building 32. This helium skid has a heat absorption capacity of 1.75 kilowatts and the capability of delivering twenty degrees kelvin helium to the

shrouds of Chamber B. Major structural elements of Chamber B are the removable top closure and the dual man locks at the floor level. The data acquisition and control rooms are located on the second floor.

This chamber is a stainless-steel vacuum vessel 10.7 meters in diameter and 13.1 meters high. It provides a working volume within a ninety degrees kelvin heat sink shroud of approximately 7.6 by 9.1 meters. Primary access for large test articles is via the 10.7-meter-diameter, removable top closure. The load-bearing floor area is 6.1 meters in diameter and will support a concentric load of 38 800 kilograms. The floor can be cooled with liquid nitrogen or heated to 390 degrees Kelvin. Two rolling bridge cranes with a capacity of 45 400 kilograms each are used to remove the chamber top closure and insert large test articles.

The dual man lock provides easy access to the test articles as well as a means of transferring test crew members to and from the test environment during manned tests. The man lock can also be used as an altitude chamber for independent tests. In addition, one man lock is equipped with a water deluge system and the other with features that permit its use for manned operations with oxygen-rich residual atmospheres. A solar simulation array, mounted on the top closure, is modular in design to facilitate changes in location and beam size to accommodate test requirements. The solar simulation modules are on-axis with xenon lamp sources. The source and collection optics are located outside the chamber, with the collimating optics inside

**the chamber.** Solar incident angles other than vertical can be achieved by installing mirrors in the chamber to redirect the solar beam. Adjustable, removable folding mirrors are available to produce solar radiation from horizontal or oblique angles. Solar intensity is variable from 0.5 to 1.5 solar constant, uniformity is plus or minus ten percent, and the decollimation half angle is within ninety minutes.

A system of mechanical roughing pumps, twenty degrees kelvin cryopumps, and valved oil-diffusion pumps provides a pumping capacity of 1.3 by  $10^3$  pascals per second for condensable gases and 26.6 pascals per second for noncondensable gases at a pressure of 1.33 by  $10^{-7}$  pascal. Usual chamber in-leakage of air is less than 399 pascals per second. The time required to reach ultimate thermal vacuum conditions is five hours.

#### General Characteristics

**OUTSIDE DIMENSIONS:** 10.7 meters in diameter by 13.1 meters high

**WORKING DIMENSIONS:** 7.6 meters in diameter by 7.9 meters high

**TEST ARTICLE WEIGHT:** 34 000 kilograms concentric load maximum

**INSTRUMENTATION:** Real-time data acquisition and remote control

**ACCESS:** Removable top head, 10.7 meters in diameter; dual man lock at floor level

#### Vacuum Systems

**TYPES OF PUMPS:** Valved and trapped oil-diffusion pumps and twenty degrees kelvin cryopumps

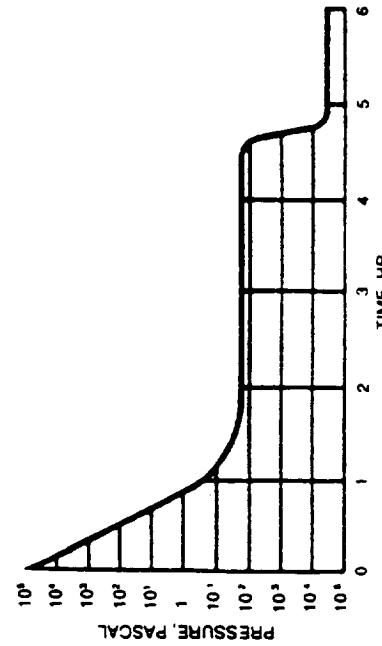
**PUMPDOWN TIME:** Five hours to ultimate pressure

**PUMPING CAPACITY:** Three by 106 liters per second condensables and two by 105 liters per second noncondensables at 1.33 by  $10^{-4}$  pascal pressure

**NOTE:** Usual chamber in-leakage is less than three by 106 liters per second of air at 1.33 by  $10^{-4}$  pascal pressure

**REPRESSURIZATION:** Emergency is a ninety second minimum; normal is controllable, with chamber dry out using dry gas purge and heated floor

#### **CHAMBER B PUMPDOWN CURVE**



Heat Sink and Special Thermal Simulators

FULL CHAMBER SHROUD: Subcooled ninety degrees kelvin liquid nitrogen shroud with 130 000 watts total heat absorption capacity and 1393 watts per square meter maximum heat flux

WALL EMISSIVITY: 0.95

SPECIAL SIMULATORS: Solar, albedo, and planetary radiation, as required.

Solar Simulation

TOP SUN: One to nineteen xenon modules producing a four meter diameter beam maximum; modules can be located anywhere within a 6.1 meter diameter circle

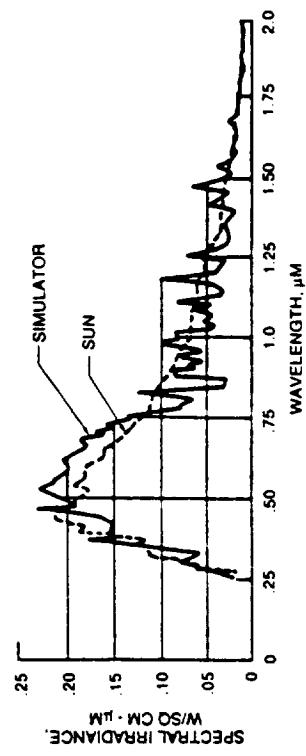
DECOLLIMATION: Ninety minute half angle

INTENSITY: 622 to 1353 watts per square meter (controllable)

UNIFORMITY: Plus or minus five percent measured by a 930-square-centimeter sensor

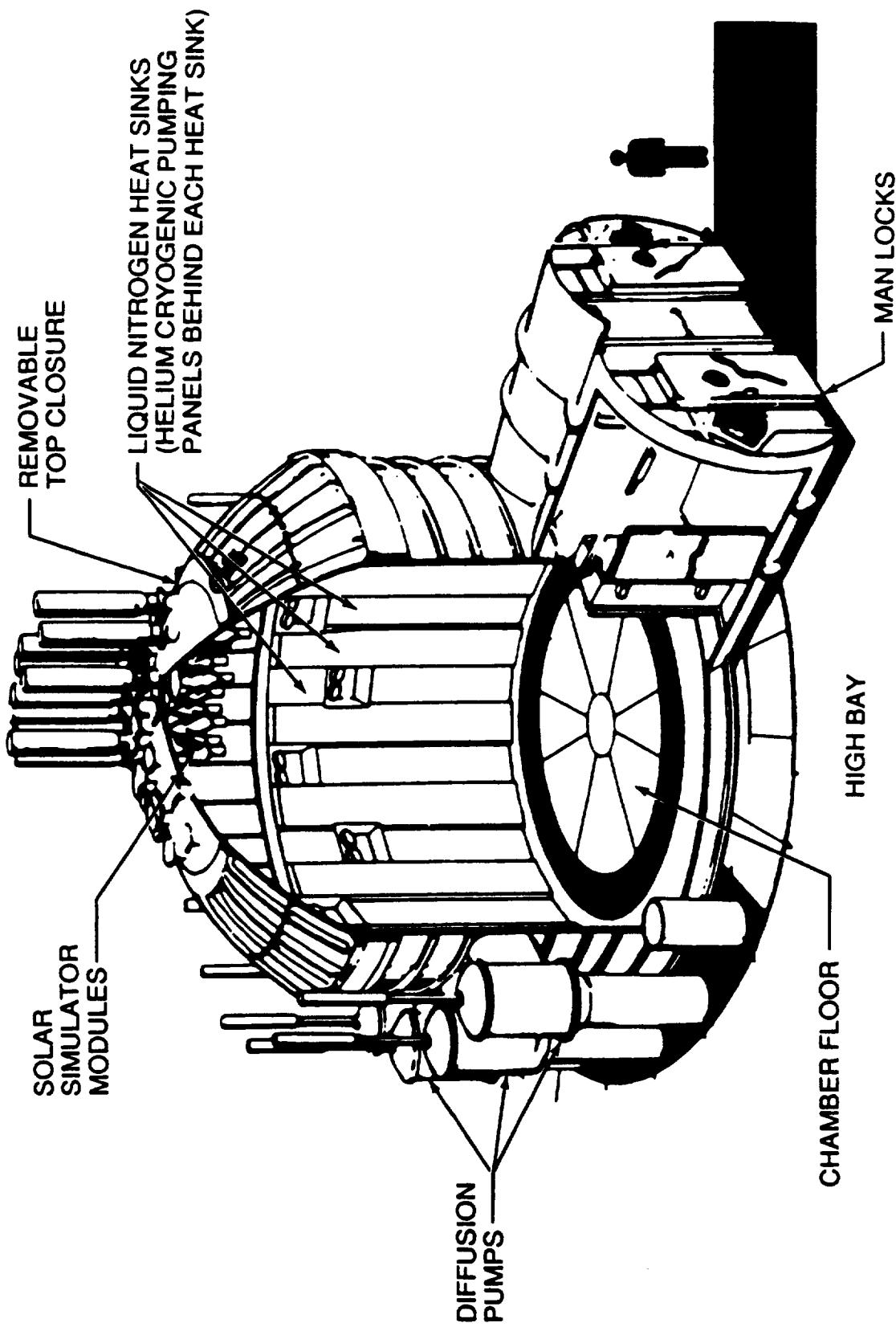
MEASUREMENT: Real-time traversing radiometer system

**SPECTRUM OF XENON SOLAR SIMULATOR MODULE**

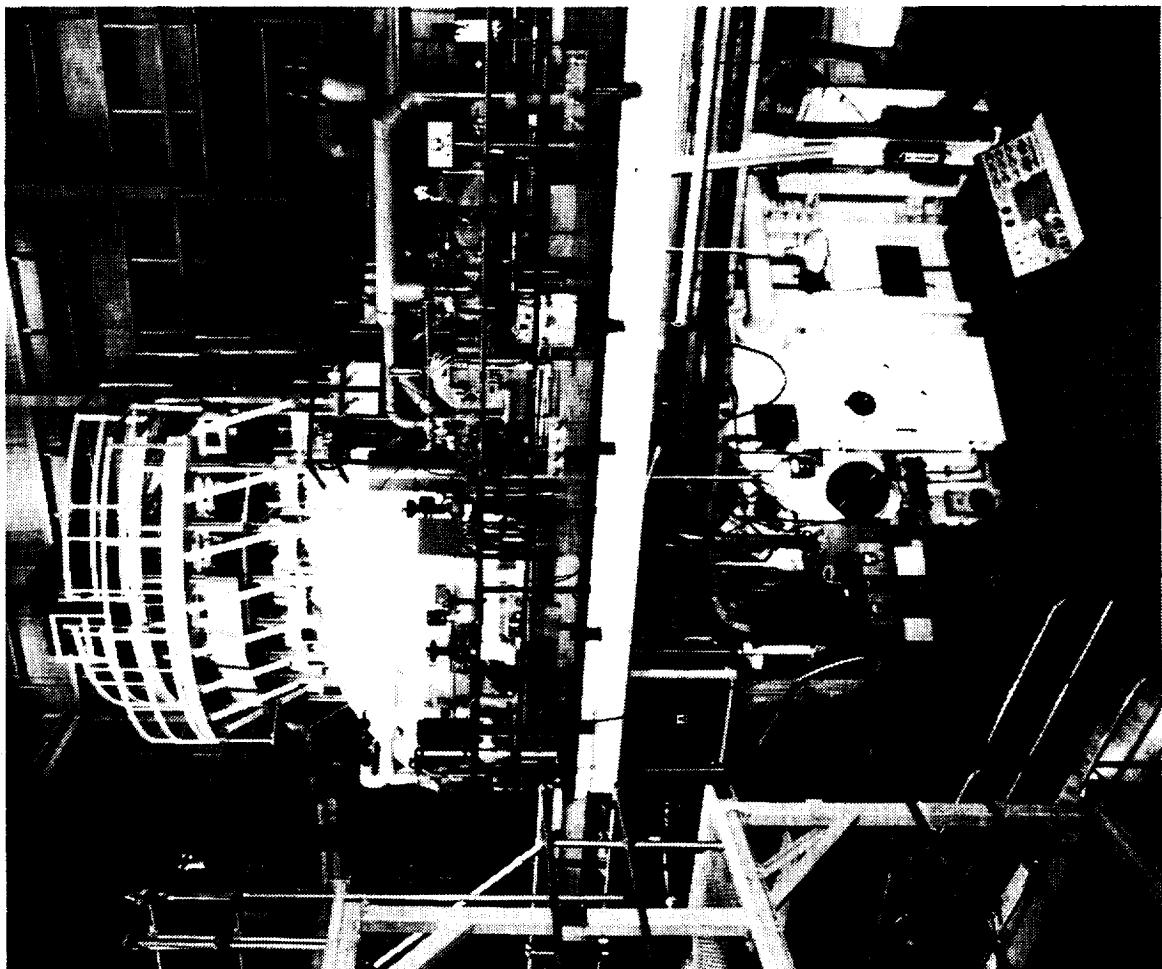


DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

## CHAMBER B HIGH VACUUM/THERMAL MAN-RATED WITH SOLAR TEST COMPLEX



**CHAMBER B HIGH VACUUM/THERMAL MAN-RATED WITH SOLAR TEST COMPLEX**



## General Facility Specifications

### CHAMBER OPERATIONS, LOCK OBSERVERS, AND PERSONNEL EQUIPMENT SHOP

LOCATION: Building 7, Room 1026.

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4, (713) 483-9208

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: Not available

REPLACEMENT COST: \$363k

USE: The shop has the capability to check out personnel equipment for all test subjects and manned test rescue team members for fit. All modifications and other work on personnel equipment is accomplished on a flow bench. The room also contains specialized dry-cleaning equipment for fire resistant garments and is also used to train personnel.

DESCRIPTION: This shop is located in Room 1026 of Building 7. The room is used to store flex hoses in an approved ready-for-use condition. A log is maintained, listing the date each flex hose passed a pressure and cleanliness test and the length of this validation. The shop is also used to store, maintain, and clean all lock observer and rescue team personnel equipment. Personnel equipment for all test subjects and manned test rescue team members is checked for proper fit and corrected in this shop. All modifications, changes, hose connections, and other work on personnel equipment is accomplished on a flow bench. This shop also contains specialized dry-cleaning equipment for fire resistant crew and lock observer garments.

DATA ACQUISITION: None.

## **General Facility Specifications**

### **CHEMISTRY LABORATORIES**

**LOCATION:** Building 7, Rooms 1001, 1023, and 2010.

**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1964

**INITIAL COST:** Not available

**REPLACEMENT COST:** \$950k

**USE:** The Chemistry Laboratories provide the capability to chemically analyze expendables which are used during systems testing and spaceflight.

**DESCRIPTION:** The advanced environmental control system Dry Gas Analysis Laboratory is located in Room 1023 of Building 7. This laboratory is used to analyze spacecraft atmospheres used in simulation testing. In addition, the laboratory analyzes the outgassing products which result from

the exposure of spacecraft and space suit materials to oxygen, heat, and a vacuum. Laboratory equipment includes gas chromatographies, mass spectrometers, an infrared spectrophotometer, and a trace gas ambient air monitor.

The advanced environmental control system Water Chemistry (Wet) Laboratory is located in Room 2010. This laboratory is used to chemically analyze expendables, such as lithium hydroxide, carbon dioxide, and water, which are used during spaceflights and tests. The laboratory contains an atomic absorption spectrophotometer, ultraviolet and visible spectrophotometer, ion chromatograph, a total carbon analyzer, refractometer, and titrators.

The water control and corrosion laboratory is located in Room 1001. This laboratory has the capability of supplying super deionized or deoxygenated water in the required quantity to exact specifications for test activities in the Crew Systems Division.

**DATA ACQUISITION:** Data acquisition is provided by discrete instrument displays and recorders.

## General Facility Specifications

### ADVANCED MATERIALS LABORATORY

LOCATION: Building 7, Room 2023.

POINT OF CONTACT: Chief, Systems Design and Analysis  
Branch, Code EC7, (713) 483-9126

STATUS: Active

YEAR BUILT: 1987

INITIAL COST: Not available

REPLACEMENT COST: \$500k

USE: The test areas in the Advanced Materials Laboratory provide the capability to test and determine the physical properties of materials. The laboratory has the facilities for development and evaluation of materials in the following areas:

- Fibers and fibrous structures
- Thermoforming and thermosetting plastics
- Elastomers
- Others (adhesives, lubricants, etc.)

This laboratory has capabilities for characterization of physical, mechanical, thermal, and flammability properties in compliance with Federal Specifications and American Society for Testing Materials Standards.

The laboratory supports the division in all advanced materials development efforts and advanced flight hardware design activities. It also supports other divisions in JSC flight hardware or flight activities. Continuous in-house testing is also conducted to investigate and evaluate new advanced materials under development.

DESCRIPTION: The Advanced Materials Laboratory is located in Room 2023 of Building 7. This laboratory is used to evaluate physical properties of materials that could be used to support many aspects of the space program. The laboratory has the capability of testing material strength, endurance, softness, stiffness, hardness, abrasion, and permeability.

DATA ACQUISITION: Data acquisition is provided by discrete instrument displays and recorders.

## **General Facility Specifications**

### **DATA ACQUISITION, RECORDING, DISPLAY, AND COMPUTER COMPLEX**

**LOCATION:** Building 7, Rooms 1005, 1005A, 1006A, and 2008; Building 32, High Bay, Rooms 219 and 220; Building 33, Rooms 107 and 118

**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4, (713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1985-88

**INITIAL COST:** \$7,400k

**REPLACEMENT COST:** \$11,880k

**USE:** The Data Acquisition Recording System and Computer Complex provides real-time data acquisition, display recording and post-test processing to support testing in Buildings 7, 32, 33, and 241. This complex also provides office automation, data base applications, and engineering and data analysis in support of the Building 7A office areas.

**DESCRIPTION:** Data acquisition, display, and recording to support all chamber facilities in Building 7 are accomplished with two separate, but similar Digital Equipment Corporation Virtual Addressing eXtended (VAX)/NEFF Data Acquisition Systems known as CTSD4 and CTSD6 systems, located in Room 1005 and Room 2008 respectively. Each system can handle up to 256 analog input channels, forty-eight analog output

channels, thirty-two discrete input channels, and thirty-two discrete output channels. Test data is displayed in real time on remote digital and graphical data terminals and recorded on magnetic tape for post-test processing. Local and wide area networks are available to provide remote real-time data monitoring by management information systems for artificial intelligence analysis.

Data acquisition, display, and recording to support Building 32 Chambers A and B are accomplished with two VAX/NEFF Data Acquisition Systems. Each system is configured with 1536 (expandable to 2560) analog input channels, forty-eight analog output channels, thirty-two discrete input channels, and thirty-two discrete output channels. The data is displayed in real time on remote data terminals and recorded on magnetic tape for post-test processing.

Another 256 analog input channel VAX/NEFF Data Acquisition System is used to support the various small chambers in Building 33.

There are eleven small, portable Hewlett Packard 9000 series Data Acquisition Systems used to support various small, long-duration tests requiring both monitoring and control.

All post-test data reduction plots, tabulations, magnetic tapes, and data files are processed utilizing the VAX/NEFF based data acquisition computer network.

The Crew and Thermal Systems Division also has a Digital Equipment Corporation VAX-8840 computer system located in Room 1005 of Building 7. This system is used for office automation, engineering analysis, and data base application.

Remote data terminals and personal computers are available in office areas of Building 7A. A VAX-6410 is used for computer-aided design and engineering applications.

## **General Facility Specifications**

### **EIGHT-FOOT CHAMBER LIFE SUPPORT SYSTEMS CANNED-MAN TEST COMPLEX**

**LOCATION:** Building 7, High Bay

**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1962

**INITIAL COST:** Not available

**REPLACEMENT COST:** \$680k

**USE:** The Eight-Foot Chamber Life Support Systems Canned-Man Test Complex facility is an altitude chamber used for canned-man testing of the Shuttle and the advanced EVA Mobility Unit, as well as life support systems. The chamber is easily adapted for manned test operations.

**DESCRIPTION:** This complex is located in the north end of Building 7 and is comprised of an altitude chamber of 2.4 meters, ancillary fluid and gas control consoles located next to the chamber, a dedicated control room located above the chamber, and a mechanical pumping system shared with the twenty-foot (6.1-meter) chamber.

The eight-foot (2.43-meter) chamber is an altitude chamber incorporating a main chamber compartment and a single airlock compartment with clean room entry. The main chamber is a

cylinder that is 2.4 meters in diameter and 4.26 meters in length. The internal volume is 19.8 cubic meters. The airlock is 2.4 meters in diameter and 1.5 meters long and has an internal volume of 5.66 cubic meters. The door of the main chamber, measuring 2.4 meters in diameter, can be opened to allow end loading of a test vehicle or large test article.

An environmental control system that can provide life support for test crewmen is integrated with the Eight-Foot Chamber facility and is used primarily for "canned-man" EVA Mobility Unit testing. This canned-man support system can also be used to simulate a crewman working. The metabolic rate can be varied from zero to in excess of 87 862.5 watts per hour. The system can simulate latent and sensible heat loads, carbon dioxide production, and oxygen consumption; it can also analyze the concentration of oxygen, water vapor, carbon dioxide, and nitrogen that may be present in the EVA Mobility Unit during a test. The life support system is being used for the design verification, off-nominal testing, and qualification testing of the mobility unit.

Special features of the Eight-Foot Chamber facility include remote actuators, an EVA Mobility Unit interface panel, a closed-circuit television, a thirteen-channel communication system, explosion-proof lighting, a fire detection and suppression system, emergency repressurization, and the capability of end loading through the rear door. A mechanical manipulator can also be operated through the rear door. All chamber operations and test article metabolic simulation operations are

controlled by an automated process control system. Additional equipment capabilities are summarized in the tables below.

The entire rear end of the eight-foot (2.43-meter) chamber is a large door that can be swung away in the event of an emergency. Fire suppression for each compartment has been approved for use in an oxygen-rich atmosphere. Water deluge quantities are given in document STB-F-208.

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

### PUMP SYSTEM CAPACITY (8 FOOT)

Pump	Capacity	Ultimate pressure	Max. rate of climb to 1.33 Pa
Beach Russ 1	10.6 m <sup>3</sup> /min		
Beach Russ 2	10.6 m <sup>3</sup> /min		
Total	21.2 m <sup>3</sup> /min	1.33 Pa	30.48 m/s

### PUMP SYSTEM CAPACITY (20 FOOT)

Pump	Capacity	Ultimate attitude	Note
Root blowers	121.7 m <sup>3</sup> /min	74 m <sup>1/2</sup>	Activated after 15 240 m is obtained with Beach Russ pumps

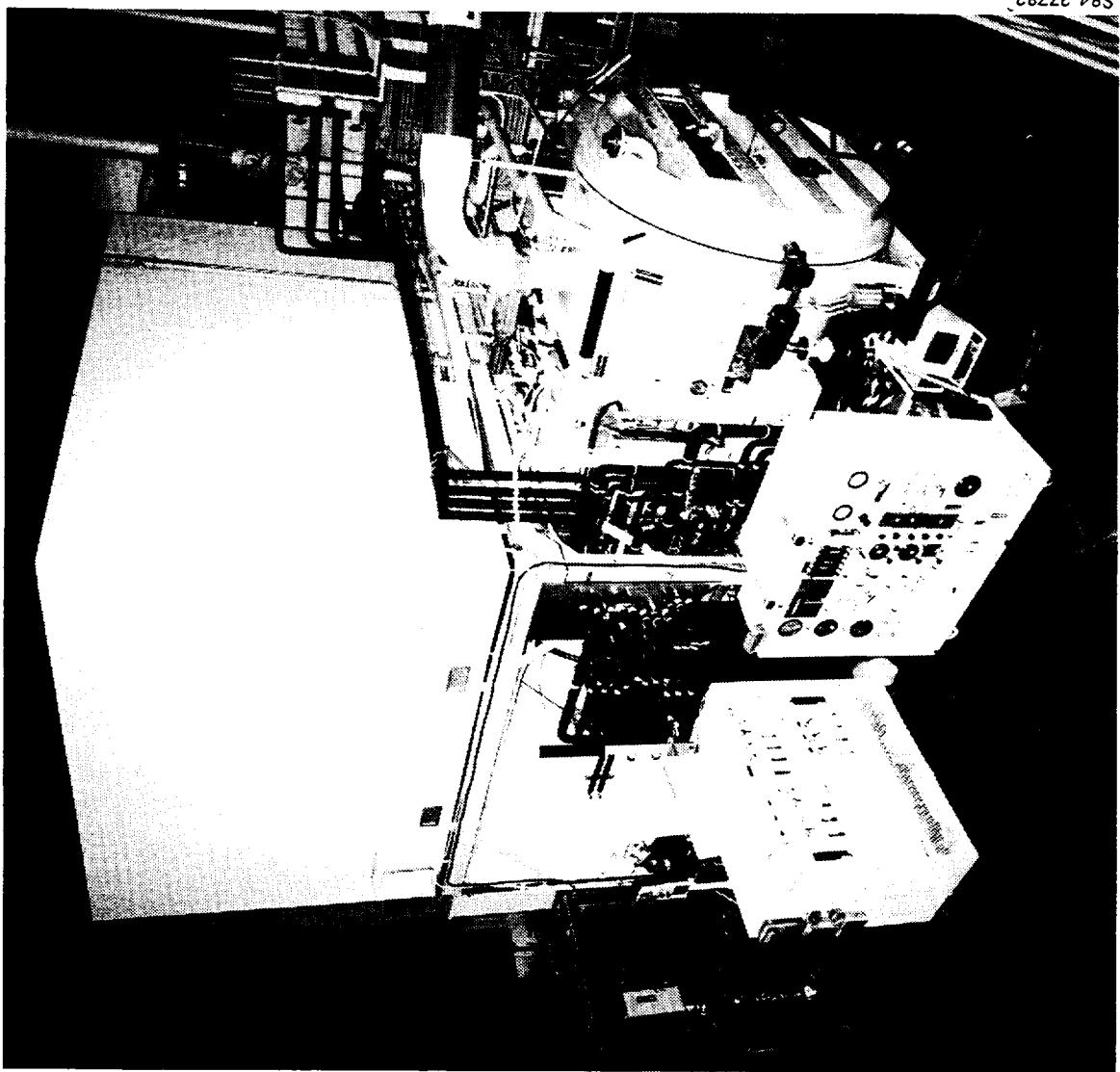
### INDIVIDUAL COMPARTMENT INTERIOR DIMENSIONS

Compartment	Size	Volume
Main chamber	2.4 m diam. by 4.26 m long	19.8 m <sup>3</sup>
Outer air lock	2.4 m diam. by 1.5 m long	5.66 m <sup>3</sup>

### CONTROL SYSTEMS

Control type	Description
Primary-electropneumatic	Normally controlled by processor controller; automatically actuated in emergency modes
Redundant-manual	Manually operated as a backup by chamber operation if primary control fails

EIGHT-FOOT CHAMBER LIFE SUPPORT SYSTEMS CANNED-MAN TEST COMPLEX



## General Facility Specifications

### ELECTRICAL FABRICATION, ELECTRONIC, AND INSTRUMENTATION SHOPS

LOCATION: Building 7, Room 1004; Building 32, Room 2201

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: Not available

REPLACEMENT COST: \$65k

USE: The Electrical Fabrication, Electronic, and Instrumentation  
Shops are equipped for design, fabrication, checkout,

installation, and repair of special electrical and electronic test  
instrumentation associated with ambient, vacuum, or thermal  
environmental testing.

DESCRIPTION: These shops are located in Room 1004 of  
Building 7 and Room 2201 of Building 32. Shop activities  
include the preparation, buildup, fabrication, repairs, and  
checkout of all instrumentation and electronic equipment  
necessary to support ambient tests or any type of chamber  
tests, including manned or unmanned, in a vacuum or thermal  
vacuum environment.

DATA ACQUISITION: None.

## **General Facility Specifications**

### **ELEVEN-FOOT CHAMBER MANNED TEST COMPLEX**

**LOCATION:** Building 7, High Bay  
**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1966

**INITIAL COST:** \$760k

**REPLACEMENT COST:** \$3,968k

**USE:** The Eleven-Foot Chamber Manned Test Complex has capability to perform environmental control and life support system testing, EVA Mobility Unit qualification, design verification, training, and vacuum testing.

**DESCRIPTION:** The Eleven-Foot Chamber Manned Test Complex consists of a control room, a pump room, and the chamber proper. The chamber is composed of four sections.

The cabin section of the chamber has a volume of 9.1 cubic meters and can be pumped down to a pressure of two pascals. This section is connected to the environmental control and life support system test article airlock by a tunnel-and-lock arrangement. This arrangement provides the capability to simulate any living space up to the combined volume of the orbiter cabin, Spacelab, and connecting tunnel.

The inner airlock section has a volume of 25.48 cubic meters and can also be pumped down to a pressure of 1.99 pascals. The inner airlock is used for astronaut EVA Mobility Unit familiarization and training. This section can accommodate two crew members simultaneously. To support dual activity, this section contains two 5/6-gram weight reducers to assist in supporting the EVA Mobility Unit weight, two treadmills that can be used for metabolic determinations, and a pumping system that is capable of handling the water load imposed by the operation of two life support systems. In addition, the pumping system can simulate a launch vehicle ascent rate during pump down.

The outer airlock section has a volume of 26.9 cubic meters and is used to maintain intermediate altitude conditions for rescue observers during manned operations inside the inner airlock. This outer airlock can also be used to transfer crew members into and out of the inner airlock at vacuum conditions.

A .6 meter diameter by .9 meter length chamber is attached to a port on the outer lock. This chamber provides an environment for evaluating extravehicular boots and gloves. Additional details on the .6 meter chamber may be found in the section "Special Test Chamber Complex." The entry room section, which is kept at ambient pressure and temperature conditions, allows clean room conditions to be maintained in the other sections of the chamber.

During Shuttle missions, the entire test complex is brought on-line in a standby mode to support the resolution of any possible mission anomalies.

**DATA ACQUISITION:** Refer to section titled **Data Acquisition, Recording, Display, and Computer Complex.**

**CONTROL ROOM FOR ENVIRONMENTAL TEST ARTICLE AND ELEVEN-FOOT CHAMBER**

**ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH**



## ELEVEN-FOOT CHAMBER TEST COMPLEX



## **General Facility Specifications**

### **HEAT PIPE AND THERMAL TEST COMPLEX**

LOCATION: Building 32, Rooms 217, 218, 220, 221, and High Bay (including the thermal test bed test enclosure)

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4, (713) 483-9208

STATUS: Active

YEAR BUILT: 1985

INITIAL COST: \$55k

REPLACEMENT COST: \$71k

USE: The Heat Pipe and Thermal Test Complex has the capability for evaluating advanced thermal management systems for long-duration space facilities, subsystems, and full-sized integrated thermal control equipment in nominal and worst-case conditions.

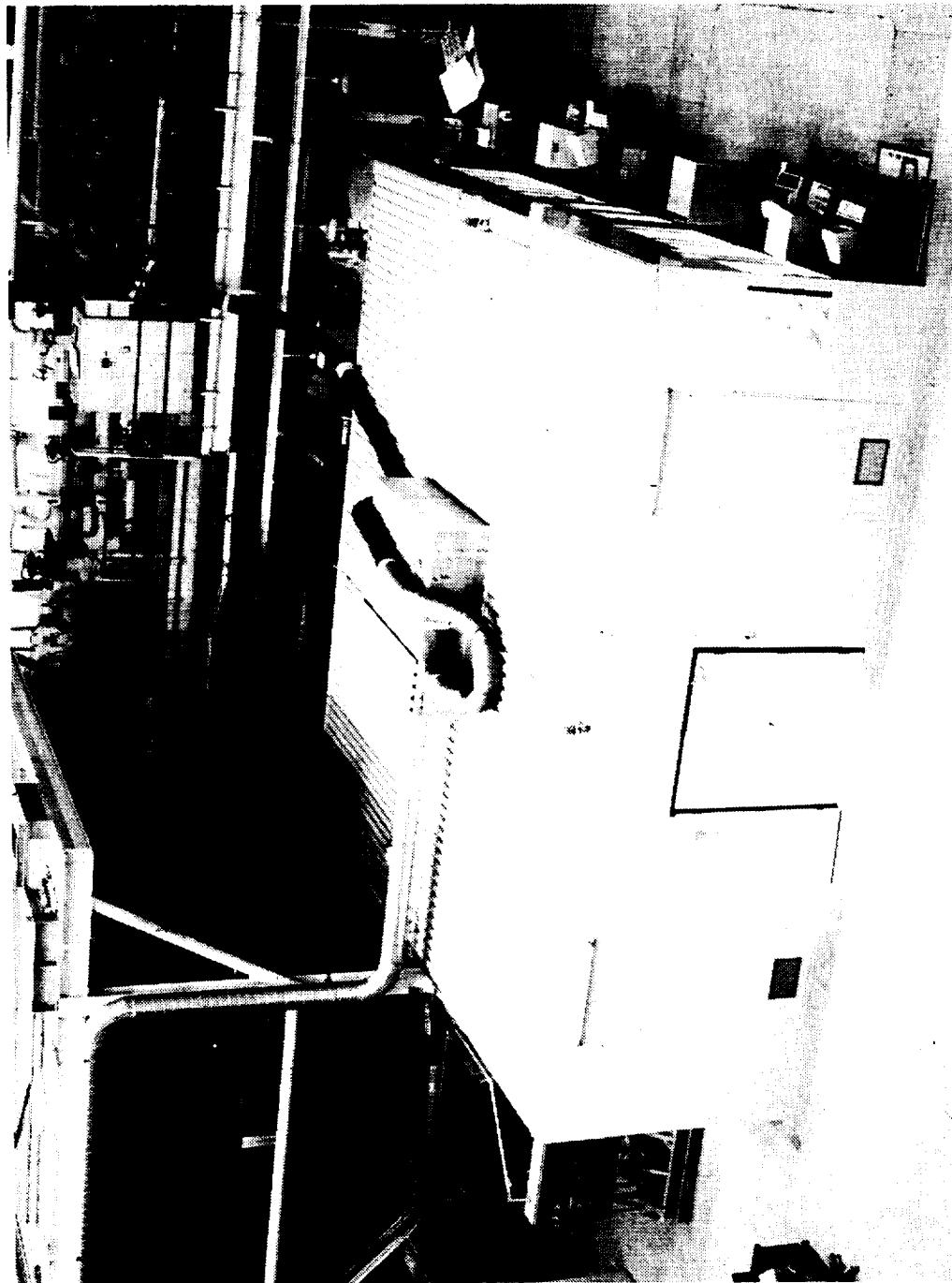
DESCRIPTION: This test complex includes the total Building 32 High Bay with test control functions and data acquisition capabilities on both the High Bay floor and on the second floor.

The unique thermal control of the permanent, manned Space Station requires the application of advanced approaches involving the use of highly-efficient, two-phase, heat pipe thermal control techniques rather than Shuttle-vintage thermal control approaches. These advanced approaches are required to make the Space Station practical and versatile from a user standpoint.

Major facilities available to support the buildup and continued operation of a thermal test complex include ample ambient laboratory floor space, vacuum and thermal vacuum chambers, fluid temperature and pressure conditioning units, a heat pipe charging and servicing facility, a heat pipe leveling and tilting fixture, a high bay test enclosure for test articles containing hazardous fluids, and an automatic data collection and processing system. This thermal test complex also provides the capability for transferring new two-phase, heat pipe technology into the Space Station development program, while simultaneously meeting the critical component issues associated with the potential application of existing single-phase fluid systems.

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

## Thermal Test Bed Test Enclosure



## **General Facility Specifications**

### **IMPACT TEST FACILITY**

**LOCATION:** Building 7, High Bay  
**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Inactive

**YEAR BUILT:** 1965

**INITIAL COST:** \$324k

**REPLACEMENT COST:** \$1,738k

**USE:** The Impact Test Facility is used for impact testing of spacecraft components, as well as testing and evaluation of crew support systems, restraint systems, force attenuations, and energy absorption systems. It is also used for qualification testing of spacecraft systems for spaceflight.

**DESCRIPTION:** This facility is used to test various couch and harness designs for their effectiveness in crew support and restraint during impact landing, various force attenuators, and energy absorption concepts and designs. Contractor-designed equipment and related techniques for these items are also tested in this facility, as well as the effects of large impact forces on the associated crew equipment and systems. This facility is used for equipment testing and is not man-rated.

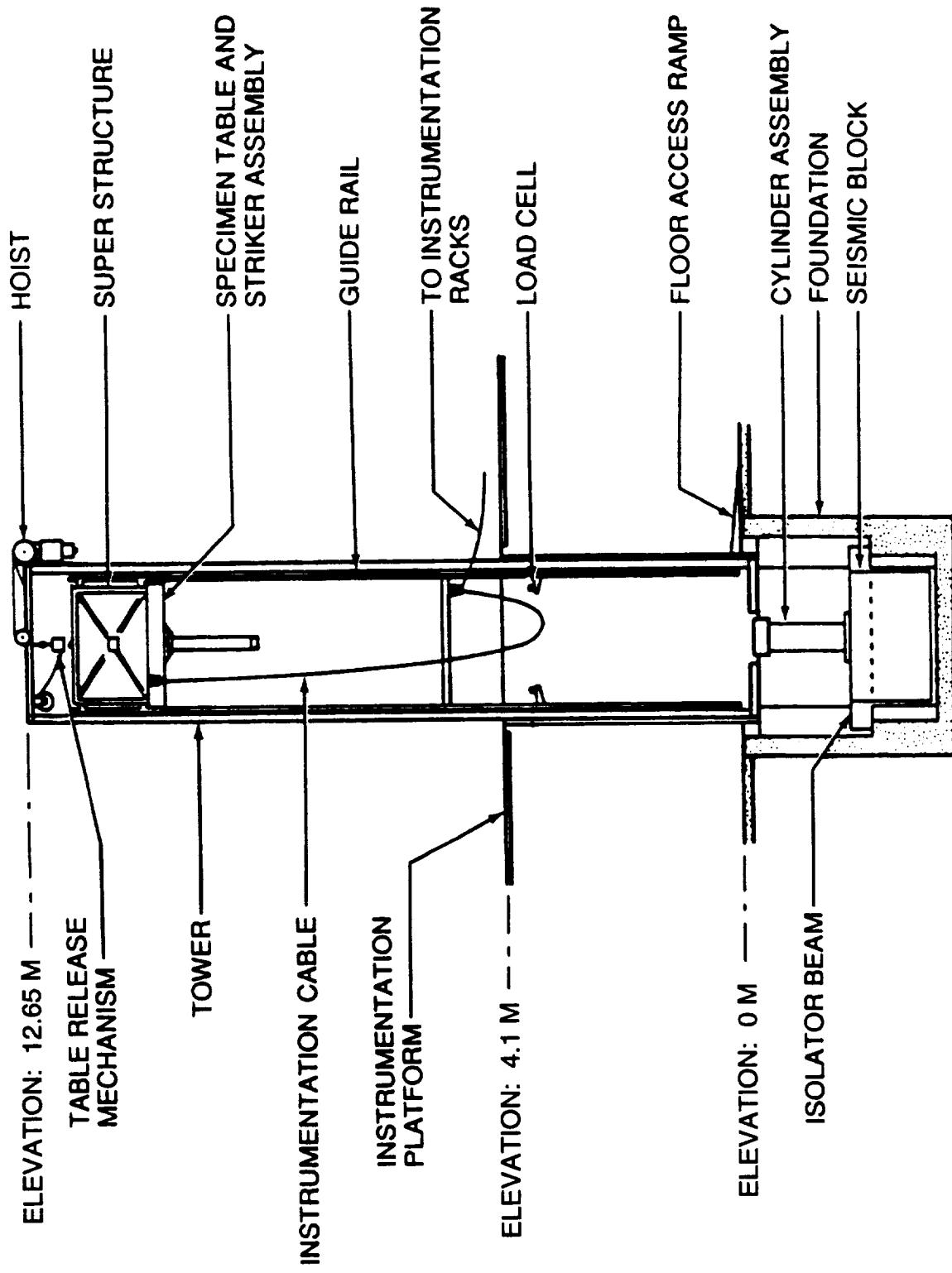
The facility consists of a 12.57-meter-high, external structure with guide rails and a hoist, a 2.13 by 2.13 meter dropping platform with an attached striker, and a hydraulic decelerator. The inner cylinder of the hydraulic decelerator is perforated with approximately six hundred holes which may be selectively unplugged to obtain the desired waveform of the decelerator time curve. A spring-loaded onset mechanism allows proper onset adjustment. The facility has the following capabilities.

- Zero to seven meters drop in height
- Zero to 11.58 meters per second velocity change
- Eight to one hundred gravity deceleration range
- Zero to 280 milliseconds time range
- Zero to ten thousand gravity per second onset
- Half-sized versine, triangular, and trapezoid wave simulation
- Payload capacity of 453 to 907 kilograms

Instrumentation includes strain gauges, transducers, accelerometers, and data acquisition equipment. A lighting system and a high-speed camera provide visual data of impact motions and stopping distances.

**DATA ACQUISITION:** Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

## IMPACT TEST FACILITY



## **General Facility Specifications**

### **INSTRUMENTATION CALIBRATION AND ELECTRONIC REPAIR LABORATORY**

LOCATION: Building 7, Room 1020B; Building 33, Rooms 116, 120, 121, and 122

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4, (713) 483-9208

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: Not available

REPLACEMENT COST: \$70K

USE: The Instrumentation Calibration and Electronic Repair Laboratory provides capabilities to calibrate, repair, and certify gauges and electronic measuring equipment.

DESCRIPTION: This laboratory is comprised of Rooms 1220B in Building 7 and Rooms 115, 120, 121, and 122 in Building 33. Rooms 1020B and 120 are equipped to calibrate and check most types of gauges and electronic measuring equipment used throughout the Crew and Thermal Systems Division test complex. Calibration of vacuum instruments is accomplished in Room 121. Records of all types of measuring equipment are maintained with traceable locations and modification listings, if any. Room 122 is utilized to repair and modify equipment as dictated by specialized test requirements or specifications. The ability to modify equipment on hand is both time and cost effective during test buildup.

DATA ACQUISITION: None.

## General Facility Specifications

### MECHANICAL SHOPS

LOCATION: Building 7, Room 1020 and High Bay; Building 32, Room 1904; Building 33, Room 124

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4, (713) 483-9208

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: Not available

REPLACEMENT COST: \$70k

USE: These shops provide support to the fabrication, installation, and checkout of mechanical test equipment used to support test programs for chambers assigned to Crew and Thermal Systems Laboratory Complex.

DESCRIPTION: These shops are located in Building 7, Room 1020 and High Bay; Building 32, Room 1904; and Building 33,

Room 124. They are used for the buildup, modification, repair, and fabrication of mechanical support equipment necessary to satisfy test program requirements for chambers assigned to the EC Division's test complex. The shop in the Building 7 High Bay contains several drill presses, grinders, metal bending equipment of different sizes, dual and mechanical back saws, and a sheet metal shearer. Racks are suspended from overhead to store tubing, unistrut, and other types of structural material commonly used. The shop in Building 32 occupies the northwest area of Room 1904. Mechanical equipment in this shop area consists of several different sizes of sheet metal bending machines, a fifteen-centimeter swing lathe, a tube bending machine, a DU-ALL saw, several small presses and punch machines, a drill press, and a curtained area for welding. Several work benches with heavy-duty vices are available. This area is used to manufacture parts and assemble test support equipment such as test article support stands, brackets, and fluid flow or temperature control carts.

DATA ACQUISITION: None.

## **General Facility Specifications**

### **SHUTTLE THERMAL AND ETA TEST AND MAN-RATED TRAINING COMPLEX**

**LOCATION:** Building 7, High Bay

**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1984

**INITIAL COST:** \$614k

**REPLACEMENT COST:** \$846k

**USE:** This complex addresses Shuttle thermal requirements, the environmental control and life support system test article (ETA), and man-rated training. It is used for crew familiarization and EVA, mission anomaly investigations, checkout, bends testing, and simulation Shuttle-cabin-to-Spacelab volumes. This complex is also used to verify capability of Shuttle active thermal control systems to satisfy thermal requirements of various payload heat inputs.

**DESCRIPTION:** This unique complex consists of various controlled and specialized equipment with the capability of supporting the training of assigned Shuttle crew members in EVA preparations and other activities, as well as subjecting the Shuttle active thermal control systems to mission expected loads and possible anomalous conditions. A major part of this complex is the environmental control and life support system

test article, known as the "ETA." It supports crew familiarization and training and consists of an oxygen-compatible, man-rated, orbiter cabin volume with an airlock attached, a tunnel adapter connecting this airlock to the eleven-foot (3.35-meter) chamber cabin section, and a rescue room connected to and located above the man lock called the airlock anteroom.

The orbiter cabin volume is suitable for testing the Atmospheric Revitalization Pressure Control System panel capability to control the environment of the cabin under various mission conditions and gas loads. In addition, this volume and panel support the investigation of possible anomalies that might develop during a mission. This volume continues to be used in obtaining data to aid in determining the optimum relation between EVA prebreathe time and cabin pressure. The airlock is used to transfer personnel, food, and equipment into and out of the cabin during long durations of testing with other than ambient conditions in the cabin. The airlock is also used to train and familiarize crew members with the EVA Mobility Unit and man lock operations prior to flight. A pneumatic hoist is attached to the outside of the top closure of the airlock to facilitate a fast egress of any crew member inside the airlock to the anteroom. The EVA Mobility Unit is attached to the inside of the airlock top closure. The tunnel adapter simulates the operational volumes of the orbiter cabin and various airlock and tunnel adapter arrangements to allow the evaluation of environmental control system and extravehicular system hardware and associated procedures.

Equally important is the eleven-foot (3.35-meter) chamber with a supporting chamber control room and a mechanical pump room which can be utilized for either this chamber or the ETA. The chamber is composed of four sections: a cabin section, an inner airlock, an outer airlock, and an entry room. Details of the eleven-foot (3.35-meter) chamber are described separately in this chapter of the catalog.

Above the eleven-foot (3.35-meter) chamber is a two-layered platform containing active thermal control systems and the flash evaporator system testbed. This testbed consists of a pair of Ling Temco Vought fabricated cold traps, a 1.8-meter diameter chamber, and supporting utilities (water, vacuum, hot dry air, and electrical power). The control consoles for this test setup are located in a concentrated area in the southwest corner of

the High Bay. The active thermal control and flash evaporator testbed is located on an overhead platform rack containing all its testbed components, the proper line lengths, and Freon-21 volumes to simulate the Shuttle active thermal control systems.

The active thermal control and flash evaporator testbed is used to troubleshoot the flight thermal control system operation, including real-time mission support. A payload support platform, approximately eighteen by nine meters, has been fabricated adjacent to, and at the same elevation as, the first layer active thermal control systems platform. This platform is used for accommodating payload testing to assess the thermal effect of various payloads on the Shuttle active thermal control systems.

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

**SPACE SHUTTLE ACTIVE THERMAL CONTROL SYSTEM AND  
FLASH EVAPORATOR SYSTEM TEST BED**



*Engineering Directorate Technical Facilities Catalog - JSC-19295*

*Crew and Thermal Systems Division (EC) – January 1993*

**ENVIRONMENTAL TEST ARTICLE EXTERIOR**

**ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH**

S84-30966



## **General Facility Specifications**

### **SOFT GOODS FABRICATION LABORATORY**

LOCATION: Building 7, Room 3001

POINT OF CONTACT: Laboratory Manager, Space Suit Systems Branch, Code EC6, (713) 483-9135

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$150k

REPLACEMENT COST: \$723k

DESCRIPTION: This laboratory, located in Room 3001 of Building 7, is designed for use in assisting JSC, other government installations, and contractors in solving software problems associated with ground and space utilization. Assistance includes the design and fabrication of packages (sized and shaped to simulate flight experiments) to be used for crew training, thermal packaging of equipment (located in the cargo bay), flight equipment (to be worn by the crew), special packaging of equipment (to be stowed in the Shuttle cabin), and many other areas of support. In addition, this laboratory can be used to conduct research and development programs completely tested and certified for use.

USE: The Soft Goods Fabrication Laboratory provides capability to design and fabricate soft good items associated with packaging flight equipment and payload protective coverings.

DATA ACQUISITION: None.

JSC BUILDING 7, ROOM 3001



S88-43538

## **General Facility Specifications**

### **SPECIAL CHAMBERS COMPLEX**

**LOCATION:** Buildings 7 and 33  
**POINT OF CONTACT:** Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

**STATUS:** Active

**YEAR BUILT:** 1966

**INITIAL COST:** \$2,029k

**REPLACEMENT COST:** \$8,919k

**USE:** The Special Chambers Complex provides various sized test chambers that can be used to simulate those thermal, vacuum, and humidity environments required for development and qualification of equipment. It is also used for experimental applications in NASA spaceflight programs.

**DESCRIPTION:** The Special Chambers Complex is comprised of fourteen test chambers offering a wide range of performance capabilities that can be matched with the individual test requirements of smaller test articles or large test article components and subsystems.

Typical uses of these chambers include developmental, engineering evaluation, and qualification testing of spacecraft components, subassemblies, and experiments; preflight thermal vacuum conditioning of flight hardware; development and

calibration of instruments for use in the large chambers or in flight; spacecraft seal studies; material, adhesive, and paint evaluations; photographic film emulsion studies; and optical surface contamination studies.

Three chambers (Chamber F, Chamber V, and the two-foot (.61-meter) chamber) are located in Building 7. Building 33 houses the remaining thirteen chambers which consist of two thermal vacuum chambers (Chambers D and E), five vacuum chambers (three-foot (.91-meter) chamber, Chambers G, P, R, and N), one bell jar (Chamber I), three temperature control chambers (Chambers H, K, and T), one humidity chamber (Chamber L), and one ultrahigh vacuum chamber (Chamber X). The thirteen chambers in Building 33 share several support systems, the principal ones being the data acquisition and control system and the liquid nitrogen storage and distribution system. The versatility of these facilities is further enhanced by a variety of auxiliary equipment that can be used as needed, such as a selection of heating and cooling shrouds and gimbaled mounting fixtures. Individual descriptions of each chamber are given in the following sections. Following the chamber descriptions, a summary table is included which compares chamber working dimensions, operating pressures and temperatures, and special features.

#### Three-Foot (.91-Meter) Chamber/Enviratron

The three-foot (.91-meter) chamber has a volume of 0.76 cubic meters and can be pumped down to a pressure of 66.6 pascals.

The interior temperature can be controlled between minus 73.3 degrees to plus 204 degrees Celsius. This chamber is self-contained in that vacuum pumps, gauges, temperature and pressure controls, and electronic recorders are mounted on the outside of the chamber. This facility provides the capability for testing space suit helmets and other small articles for expected space use environments.

#### Two-Foot (0.61-Meter) Chamber

The two-foot (0.61-meter) chamber has a volume of 0.25 cubic meters and can be pumped down to a pressure of 0.05 pascals. This chamber is attached to a port in the outer airlock of the eleven-foot (3.35-meter) chamber. The two-foot (0.61-meter) chamber contains a thermal shroud and a quartz lamp array which allow controlled temperature testing between plus 140.8 degrees Celsius and minus 184 degrees Celsius. This chamber provides an environment for evaluating space suit boots and gloves. It can also be used to provide requested profiles of outgassing, water boil-off, and leaks for future prototype boot and glove systems. The chamber is 0.6 meters in diameter and 0.9 meters in length. The vacuum system uses a Consolidated Vacuum Corporation 0.5-meter diameter diffusion pump.

#### Chamber D

Chamber D is the largest chamber in the complex. It is a medium-sized bakeable chamber designed for relatively large gas loads at ultrahigh vacuum. It is equipped with an off-axis filtered xenon solar simulator, cold walls, and a variety of pumping systems suitable for trace-contaminant-sensitive tests.

- Usable dimensions (without solar): 1.8 meter diameter by 4.1 meters
- Usable dimensions (solar): 1.1 meter diameter by 1.8 meters
- Pump-down time: twelve hours to ultimate pressure
- Vacuum: 0.13 by  $10^{-4}$  pascal
- Thermal shroud: eighty to five hundred degrees kelvin

The chamber is a stainless-steel cylindrical vessel, 2.74 meters in diameter and 6.1 meters high. Test articles weighing up to 906 kilograms may be inserted into the chamber through a removable lower section powered by three electrical screw jacks. This arrangement enables test articles to be positioned and fully checked out prior to final installation in the chamber. Numerous penetrations through this lower section provide fluid, electrical, and instrumentation connectors to the test article. Several different pumping systems are available to be used in combination or separately. These consist of a mechanical pump; a twenty-degrees-kelvin, twenty-two-square-meter cryopumping system; a liquid nitrogen pump; and a baffled oil-diffusion pump. Normal pump-down time is twelve hours to ultimate pressure. The off-axis filtered xenon short-arc solar simulator system intensity is controllable from 0.46 to 1.00 solar constant. Uniformity is plus or minus eight percent, and the decollimation half-angle is 1.5 degrees. The solar beam is directed to a pre-positioned, 1.1-meter mirror in the top closure of the chamber, which reflects the beam down into the chamber. Except for the solar simulation reflecting mirror, the test volume is surrounded by high-emissivity heat sink panels maintained at eighty degrees Kelvin. Equipment is available to build up custom albedo and planetary radiation simulators for tests where they are required. Several fixtures are also available to rotate and tilt test articles relative to the solar or heat flux fields.

- Solar simulation: 1.1 meter diameter beam
- Access: removable floor

#### Chamber E

The second largest chamber in the complex is also designed for relatively large gas loads at high vacuum. It is equipped with cold walls, an on-axis filtered xenon solar simulator, and pumping systems suitable for trace contaminant sensitive tests. The xenon solar simulator is attached to the back closure and is removable when not required. The interior thermal shroud is also removable.

- Usable dimensions (without solar): 1.4 meter diameter by 2.9 meters
- Usable dimensions (solar): 1.1 meter diameter by 1.8 meters
- Pump-down time: eight hours
- Vacuum: 0.13 by  $10^{-4}$  pascal
- Thermal shroud: eighty to five hundred degrees kelvin
- Solar simulation: 1.1 meter diameter beam
- Access: end door

#### Chambers F and G

These two chambers are twins in size, shape, arrangement, and function. Both are small bakeable chambers equipped with cold walls and solar simulation provisions. A quartz view port is located in the hinged door on the front of each chamber. A portable sungun can be positioned to irradiate the interior volume with a 0.15 meter diameter beam. The interior thermal shroud is removable.

- Usable dimensions: 0.4 meter diameter by 0.6 meter
- Pump-down time: six hours to ultimate pressure
- Vacuum: 0.13 by  $10^{-4}$  pascal
- Thermal shroud: eighty to five hundred degrees kelvin
- Solar simulation: 0.15 meter diameter beam
- Access: end door

#### Chamber H

Chamber H is a programmable temperature enclosure for large test articles. It is automatically controlled to a user-defined temperature profile. Cooling is provided by an open loop liquid nitrogen heat exchanger, and heating is accomplished by electric resistance heaters. The chamber air is circulated across the heat exchanger and heater coils with a wide dispersal of the output stream for uniform temperature distribution.

- Usable dimensions: 2.4 by 2.4 by 4.6 meters
- Temperature extremes: minus 101 degrees to plus 65 degrees Celsius
- Cooling/heating rate: two degrees Celsius per minute
- Access door: 1.78 by 2.08 meters tall
- Observation panels: two windows
- Glove ports: two ports (one beneath each window)
- Feed throughs: two sized at ten by ten centimeters

#### Chambers I and V

These two chambers are high-vacuum pumping stations normally configured with a bell jar. The vacuum system consists of a mechanical pump and an oil diffusion pump. Electrical heaters are used if thermal effects are required.

Tests in these chambers have included studies of vacuum gauges, materials, outgassing, degradation of materials, and the determination of the survival lifetime of spores under high-vacuum conditions.

- Usable dimensions: 0.5 meter diameter by 0.6 meter
- Pump-down time: two hours to ultimate pressure
- Vacuum: 0.13 by  $10^{-3}$  pascal
- Access: removable top

#### Chamber K

This thermal shroud test chamber is used to test experiments or materials at elevated or reduced temperatures. The chamber is microprocessor controlled.

- Usable dimensions: one by one by one meter
- Thermal shroud: 198 to 383 degrees kelvin
- Access: hinged door

#### Chamber N

This medium-sized chamber has a high-vacuum capability, cold walls, and solar simulation provisions. In addition to its use for spacecraft component tests, it is frequently used for calibration of radiometers for the Chambers A and B radiation intensity measuring system. A quartz view port is located in the hinged door on the front of the chamber. A portable sungun can be positioned to irradiate the interior volume with a 0.15 meter diameter beam. The interior thermal shroud is removable.

- Usable dimensions: 0.9 meter diameter by 0.9 meter
- Pump-down time: four hours to ultimate pressure
- Vacuum: 0.13 by  $10^{-3}$  pascal
- Thermal shroud: eighty degrees Kelvin to ambient
- Solar simulation: nineteen centimeter diameter beam
- Access: end door

#### Chamber P

This medium-sized bakeable vacuum chamber is equipped with a thermal shroud. It is frequently used for outgassing tests of materials and test articles scheduled for testing in other chambers. Provisions are available for the collection of outgassing samples which can be transferred to the laboratory for analysis.

- Usable dimensions: 1.5 meter diameter by 1.2 meters
- Pump-down time: six hours to ultimate pressure
- Vacuum: 0.13 by  $10^{-4}$  pascal
- Thermal shroud: ambient to 450 degrees Kelvin
- Access: hinged end door

#### Chamber L

Chamber L is a high-humidity test chamber with automatic humidity control. Typically, it has been used to test materials, components, and experiments for the effects of high-humidity environments in places such as space vehicle launch sites.

- Usable dimensions: 0.6 by 0.9 by 0.9 meter
- Humidity: thirty-five to ninety-eight percent relative humidity
- Temperature range: 260 to 363 degrees kelvin
- Access: hinged double door

### Chamber R

Chamber R is a small, high-vacuum chamber equipped with liquid nitrogen cold walls. Vacuum is generated using a mechanical roughing pump and an oil diffusion pump. Access is via the front door and test article support structure mounted on drawer style rollers for ease of test article loading.

- Usable dimensions: 0.6 by 0.6 by 0.6 meters
- Thermal shroud: eighty degrees Kelvin
- Access: end door
- Feed throughs: three at 152-millimeter diameter

### Chamber T

This programmable temperature enclosure can be automatically programmed to both temperature extremes using a microprocessor. Cooling is accomplished by selecting either a hermetically sealed cascade mechanical refrigeration system or a liquid nitrogen refrigeration system. Heating is accomplished by indirect heating of circulated air.

- Usable dimensions: 0.9 by 0.9 by 0.9 meter
- Temperature extremes: eighty to 366 degrees Kelvin
- Cool-down time: ambient to two hundred degrees Kelvin in one hour

- Heat-up time: ambient to 366 degrees Kelvin in one hour
- Access: 0.9 by 0.9 meter door
- Observation panel: 0.47 by 0.47 meter window
- Feed through: two 10.6 centimeter square parts and six 1.58 centimeter diameter tubes

### Chamber X

This small vacuum chamber tests component reaction and operation in a vacuum environment. Test articles can be checked for proper mechanical function within the chamber by means of a mechanical feed through that allows mechanisms to be actuated from outside the chamber. Chamber X is used for in-house research and development studies to support tests in other chambers.

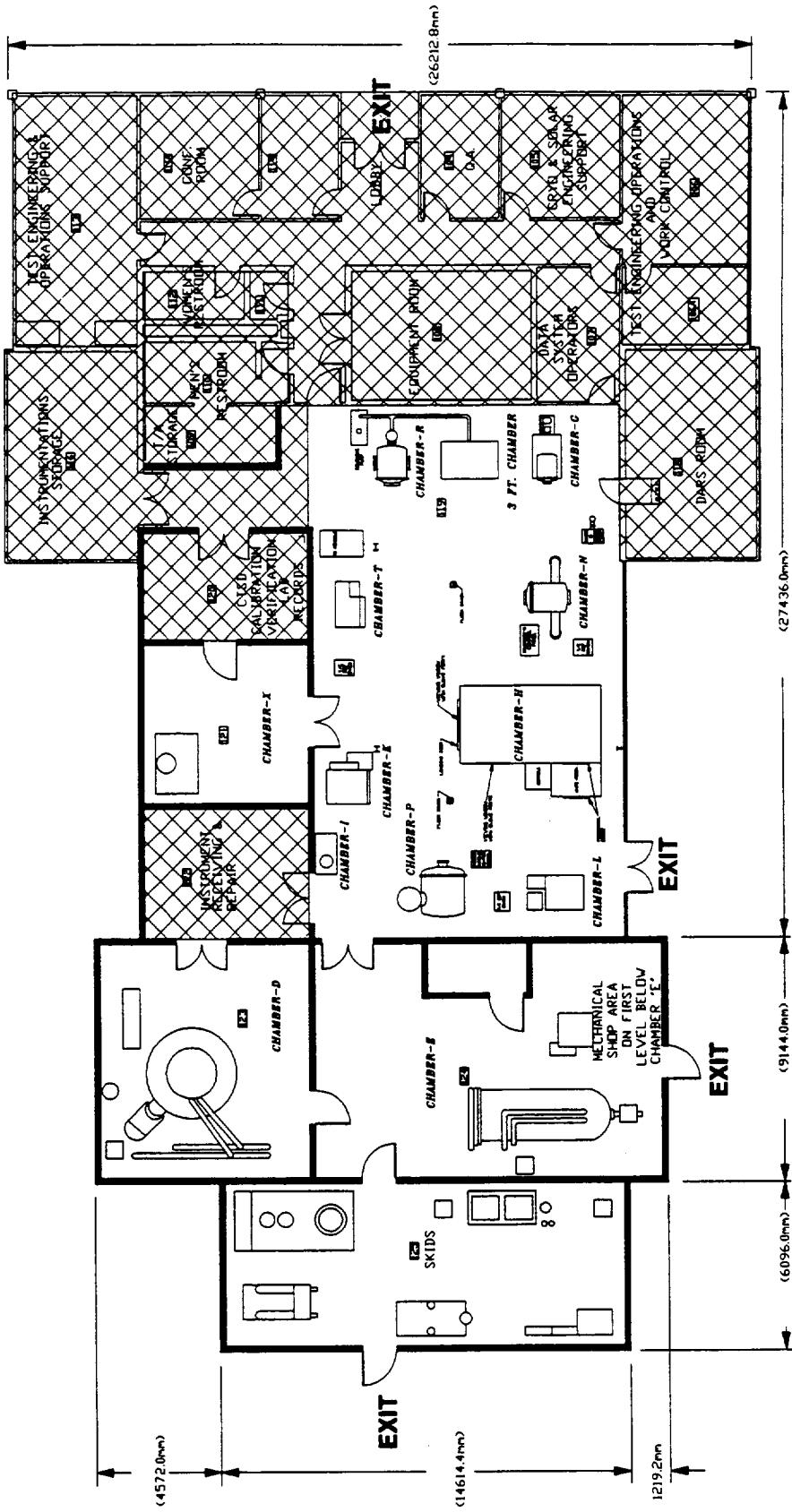
- Usable dimensions: 0.6 meter diameter by 0.4 meter
- Pump-down time: eight hours to ultimate pressure
- Vacuum: 0.13 by 10<sup>-5</sup> pascal
- Thermal: eighty to 500 degrees Kelvin
- Access: removable top

DATA ACQUISITION: Refer to section titled Data Acquisition, Recording, Display, and Computer Complex.

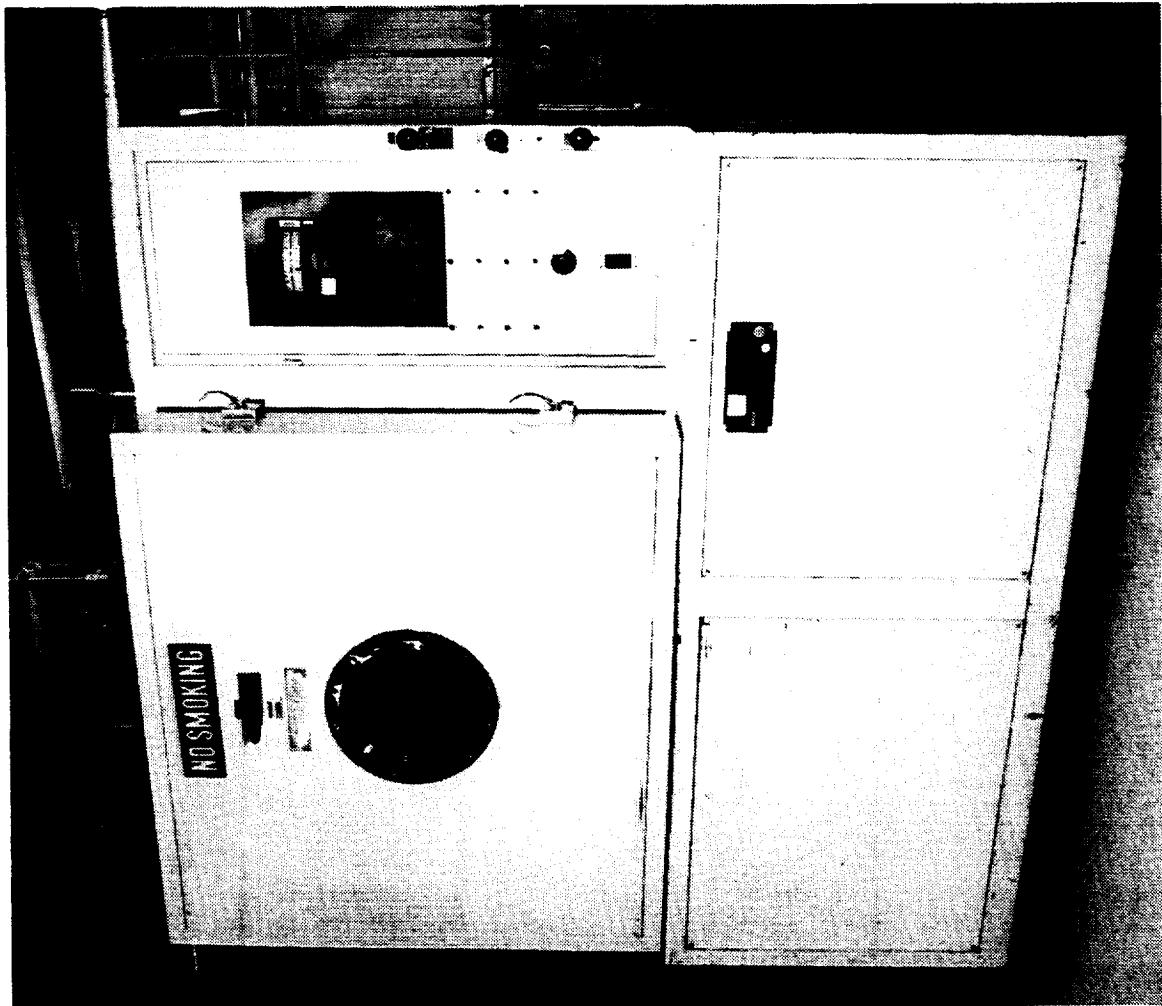
## CHAMBER CAPABILITY SUMMARY

Chamber	Size	Solar	Operating pressure (Pa)	Features
3-ft	0.9 by 0.9 m	No	$66.6 \times 10^{-1}$	-73 °C to + 204 °C, self-contained controls
2-ft	0.6 m diam. by 0.9 m	No	$5.3 \times 10^{-5}$	-184 °C to + 148 °C
D	1.8 by 4.1 m	Yes	$1.33 \times 10^{-7}$	Vertical chamber with bottom load and mechanical feedthrough
E	1.4 by 2.9 m	Yes	$1.33 \times 10^{-7}$	Horizontal chamber with hinged end door
F	0.4 by 0.6 m	No	$1.33 \times 10^{-7}$	Hinged end door and removable shroud
G	0.4 by 0.6 m	No	$1.33 \times 10^{-7}$	Hinged end door and removable shroud
H	2.4 by 2.4 by 4.6 m	No		Walk-in chamber
I	0.5 by 0.6 m	No	$1.33 \times 10^{-6}$	Bell jar with removable top
K	1 by 1 by 1 m	No		198 K to 383 K temperature chamber
L	0.6 by 0.9 by 0.9 m	No		260 K to 363 K and up to 98 percent relative humidity
N	0.9 by 0.9 m	No	$1.33 \times 10^{-6}$	Hinged end door, removable shroud, and mechanical feedthrough
P	1.5 by 1.2 m	No	$1.33 \times 10^{-7}$	Hinged end door, removable shroud, and ambient to 450 K temperatures
R	0.6 by 0.6 by 0.9 m	No	$1.33 \times 10^{-7}$	
T	0.9 by 0.9 by 0.9 m	No		80 K to 366 K temperature chamber
V	0.5 by 0.6 m	No	$1.33 \times 10^{-6}$	Bell jar with removable top
X	0.6 by 0.4 m	No	$1.33 \times 10^{-8}$	Removable top and mechanical feedthrough

## JSC BUILDING 33, FLOOR PLAN

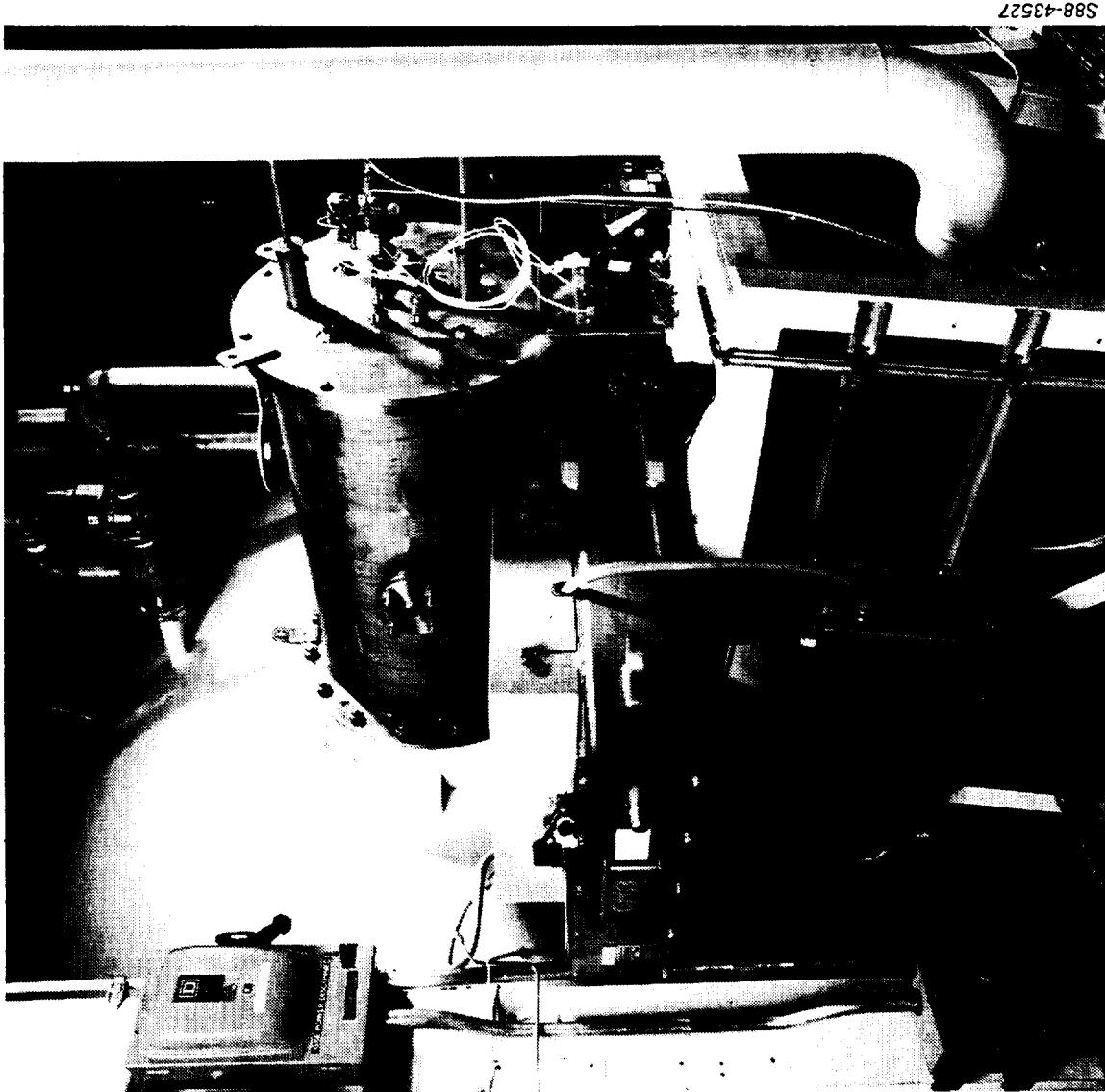


## THREE-FOOT CHAMBER/ENVIRATRON

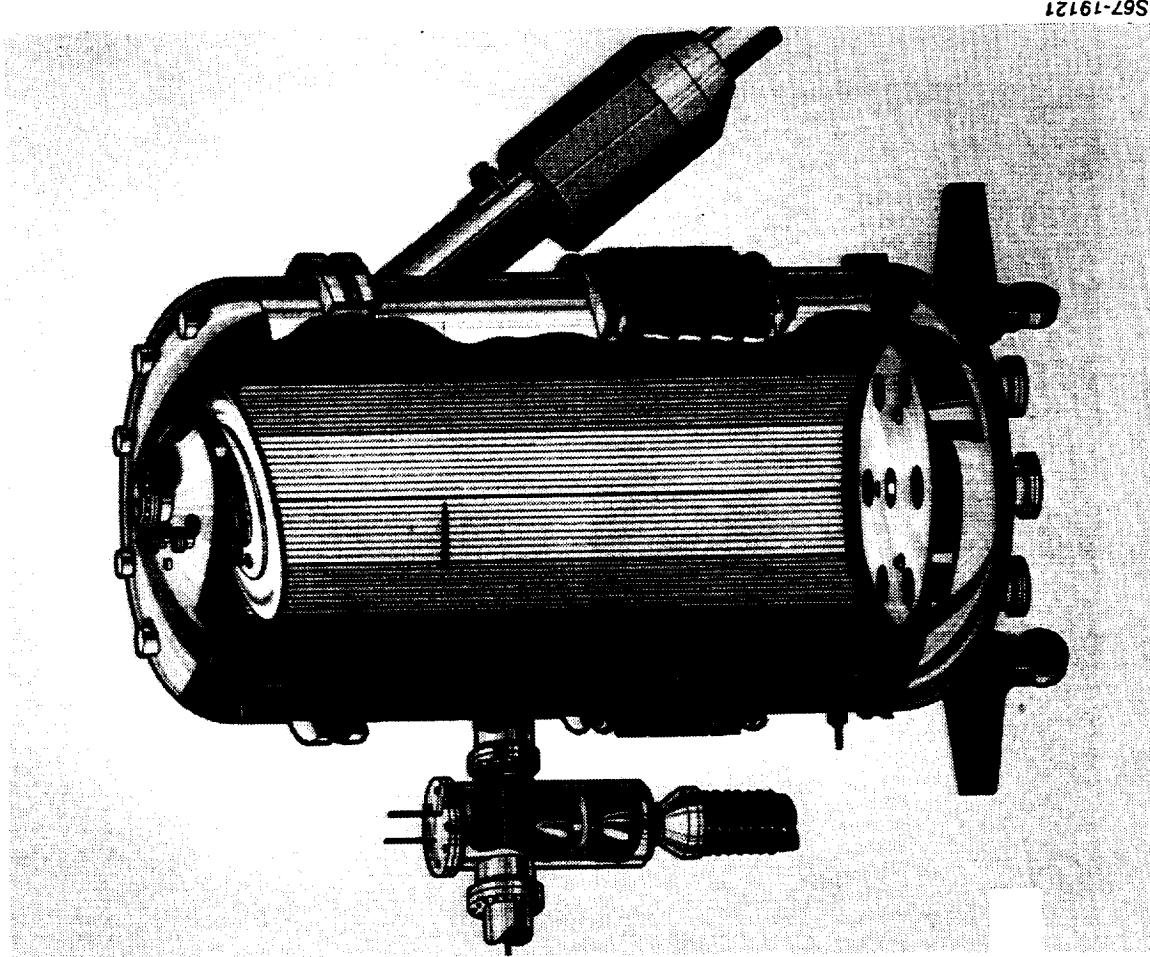


TWO-FOOT CHAMBER

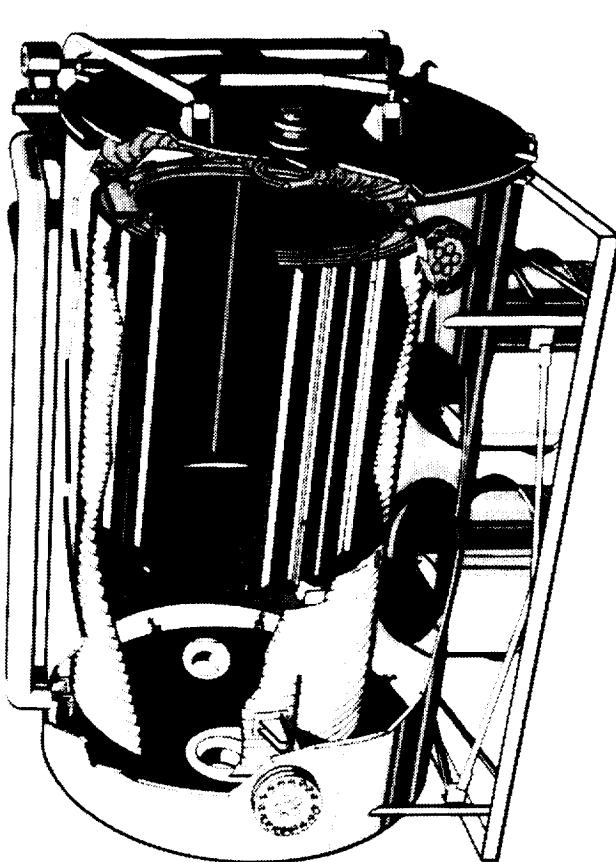
ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH



**CHAMBER D**

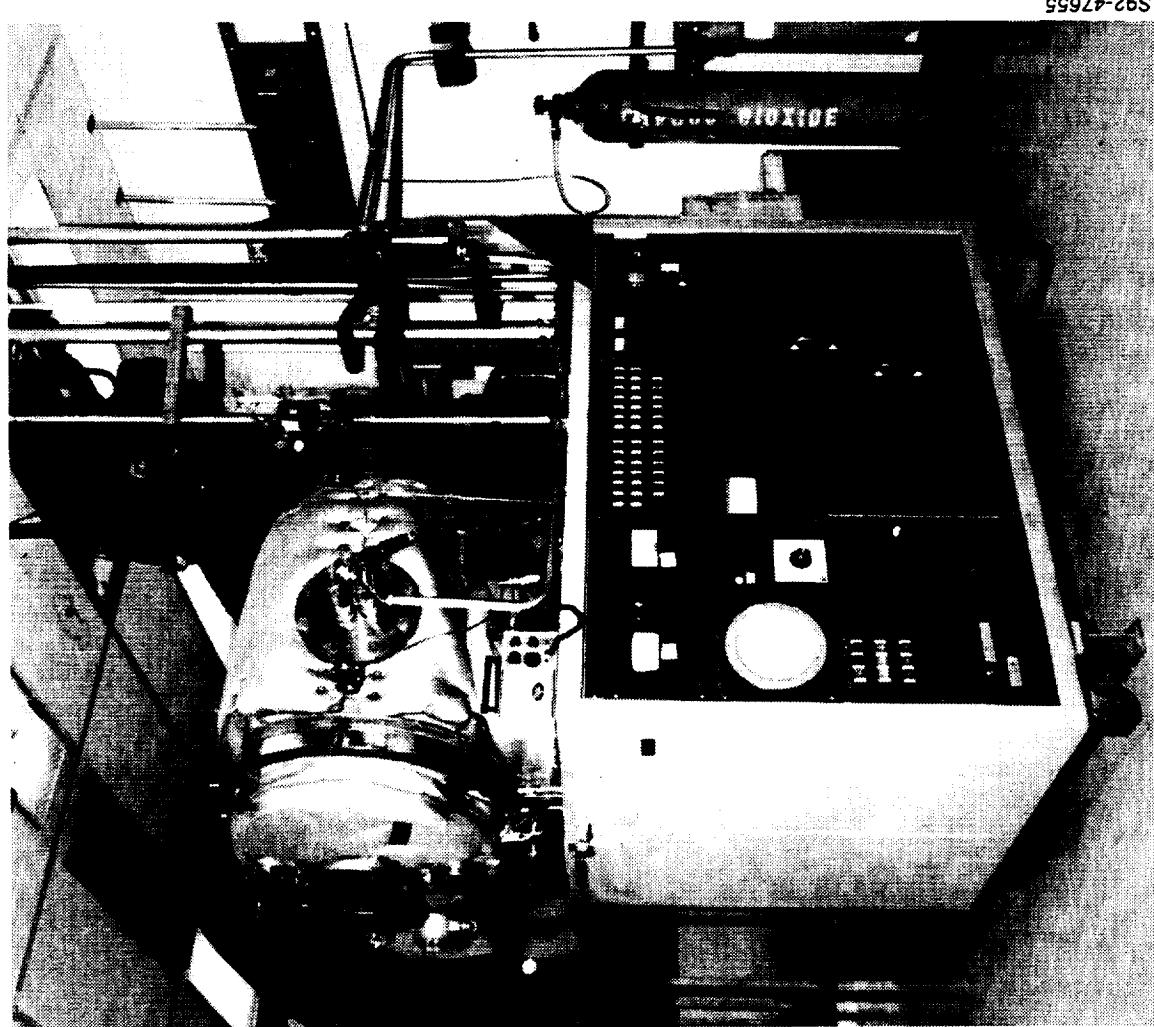


**CHAMBER E**

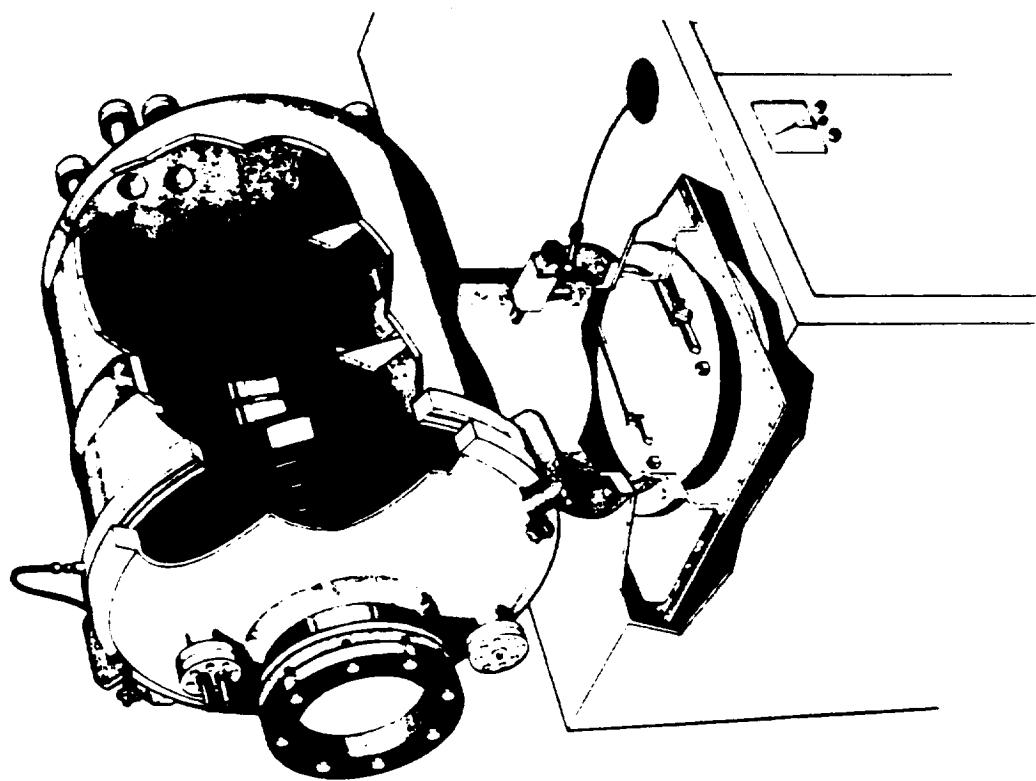


S67-19127

**CHAMBER F**



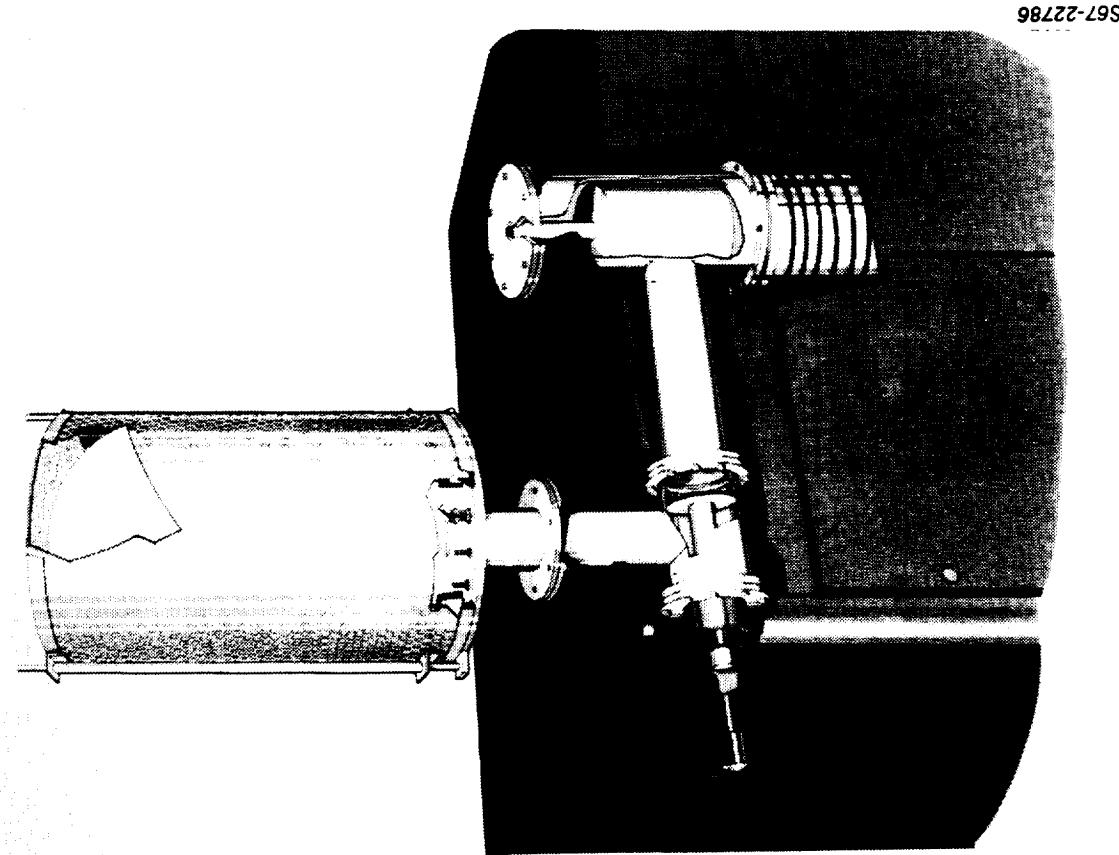
**CHAMBER G**



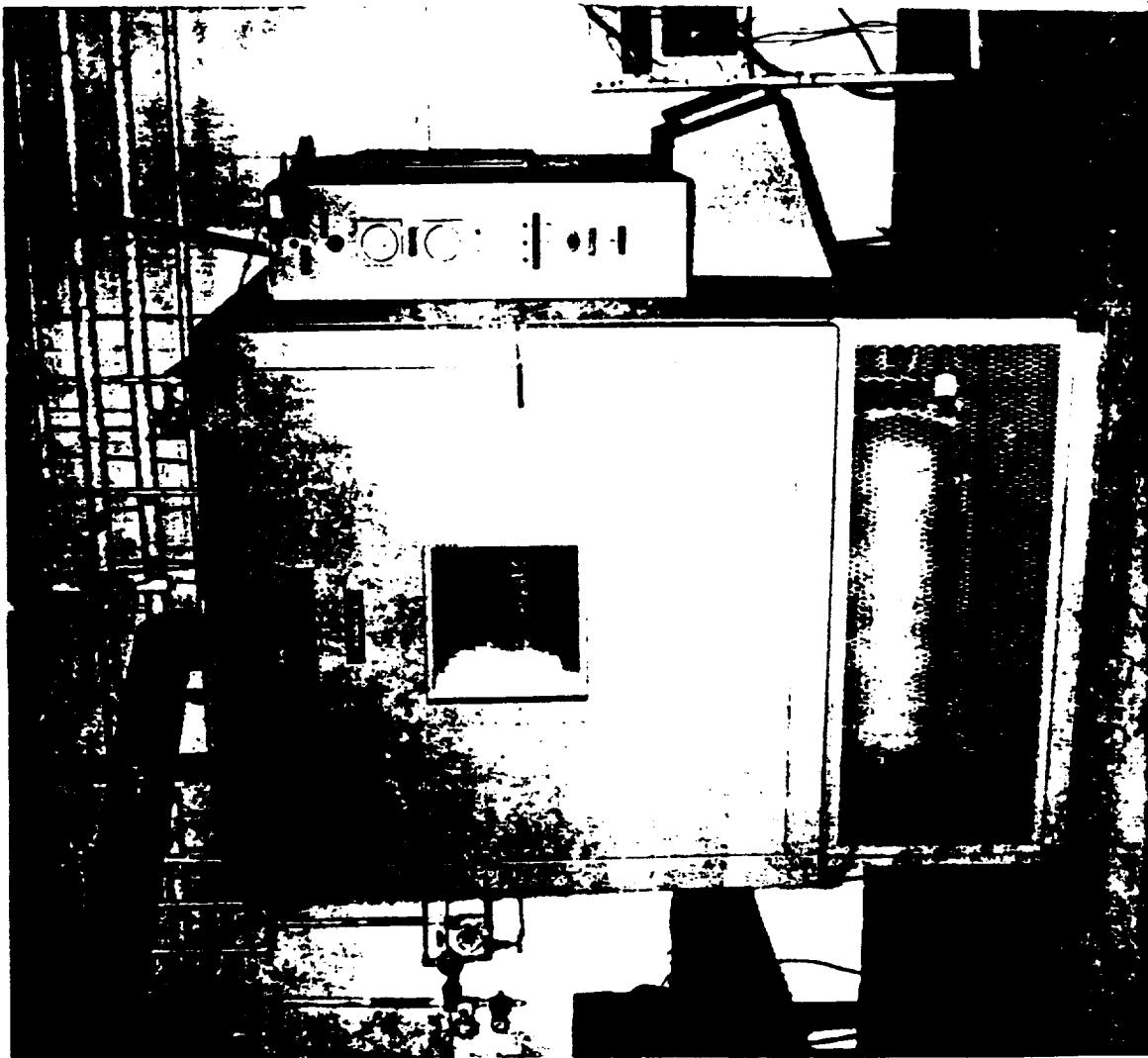
**CHAMBER H**



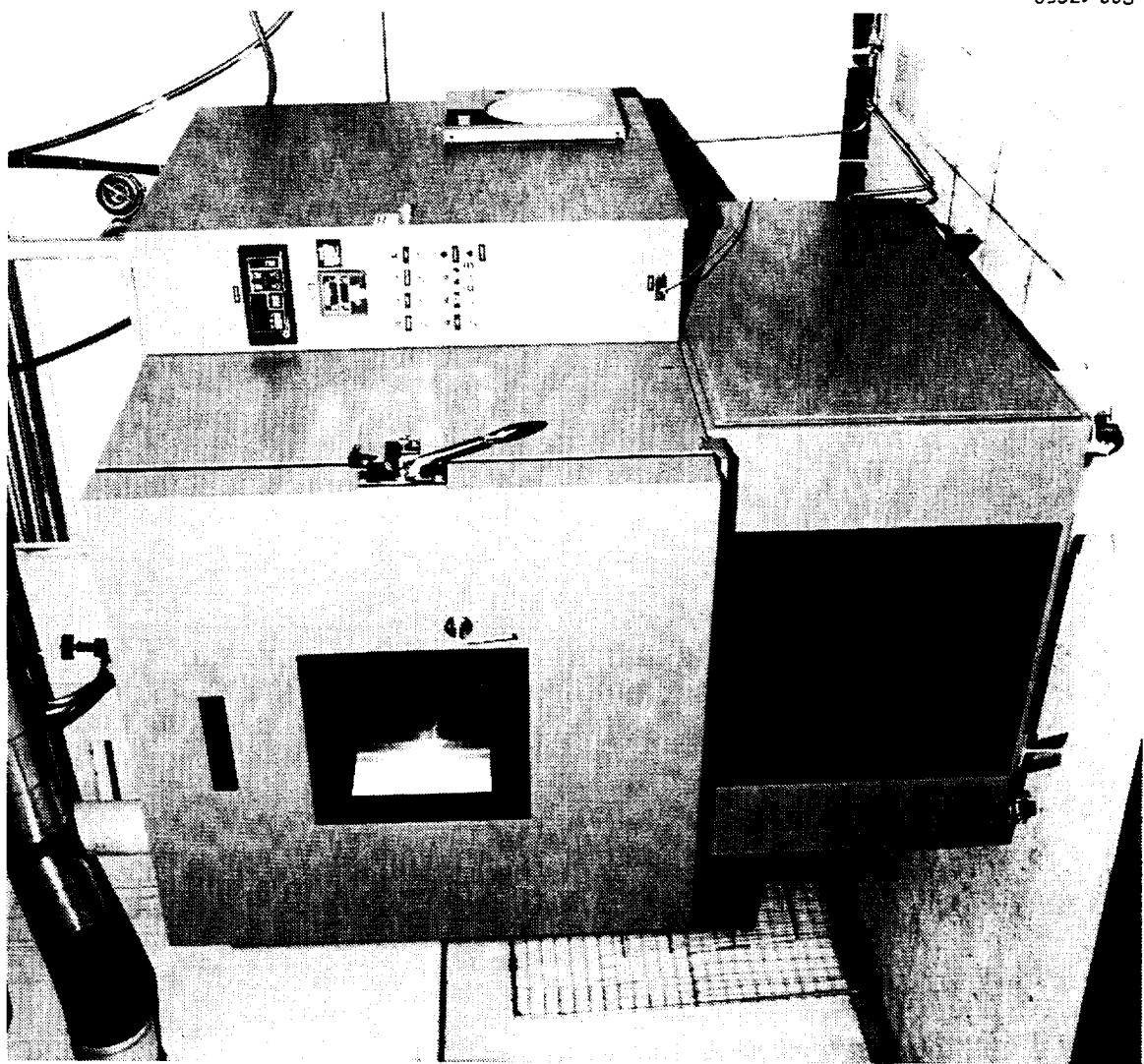
**CHAMBER I**



**CHAMBER K**

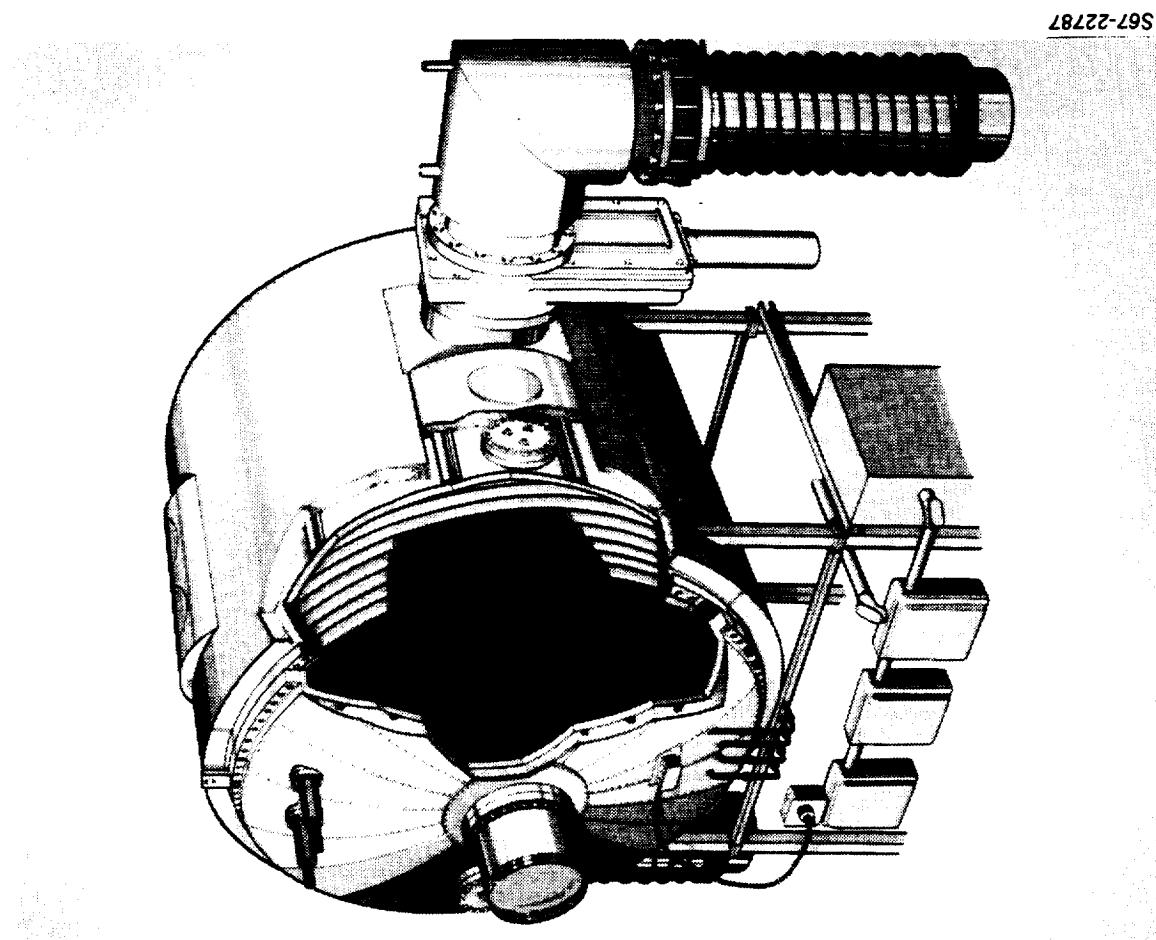


CHAMBER L

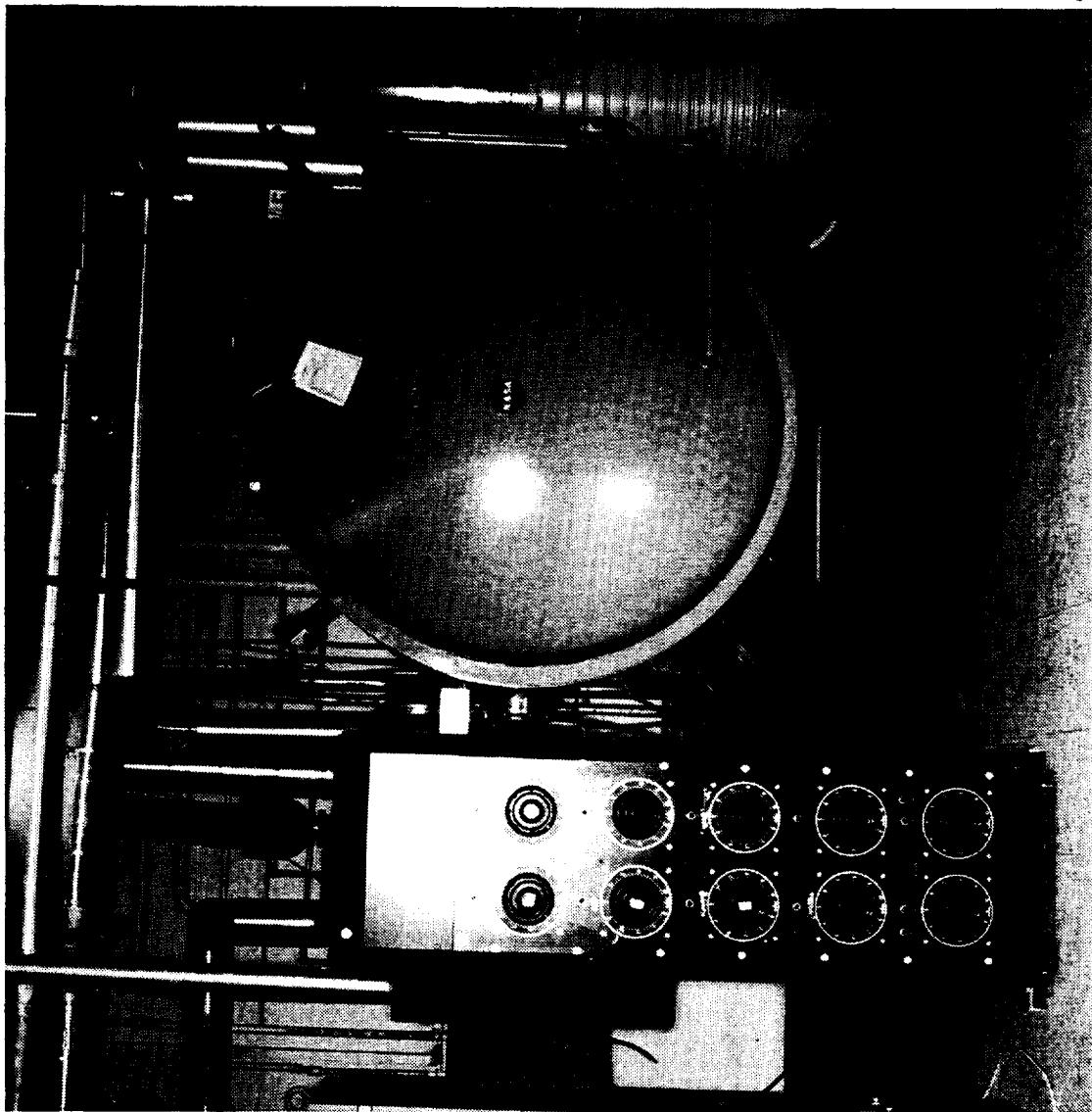


S92-47658

**CHAMBER N**

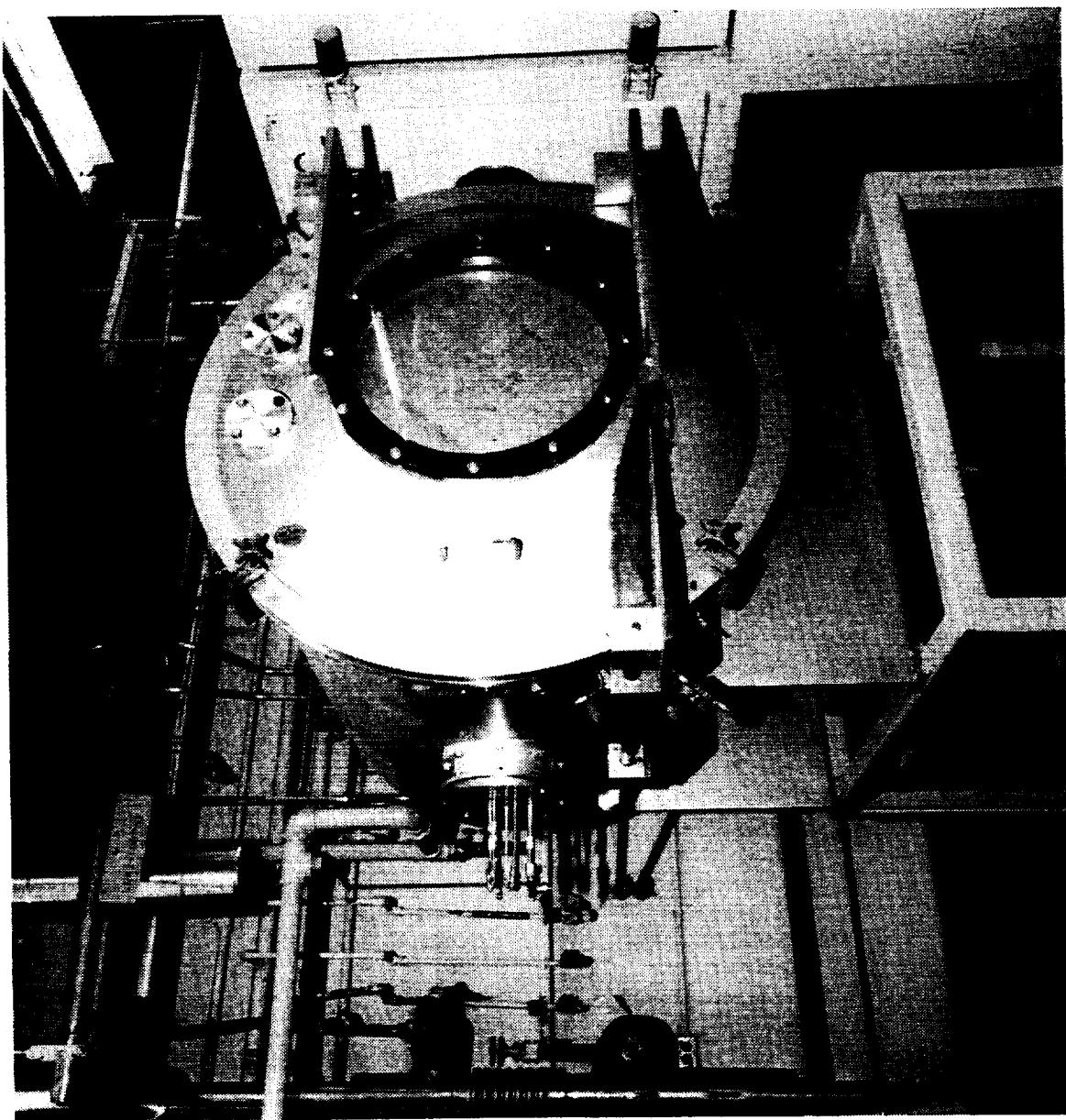


**CHAMBER P**

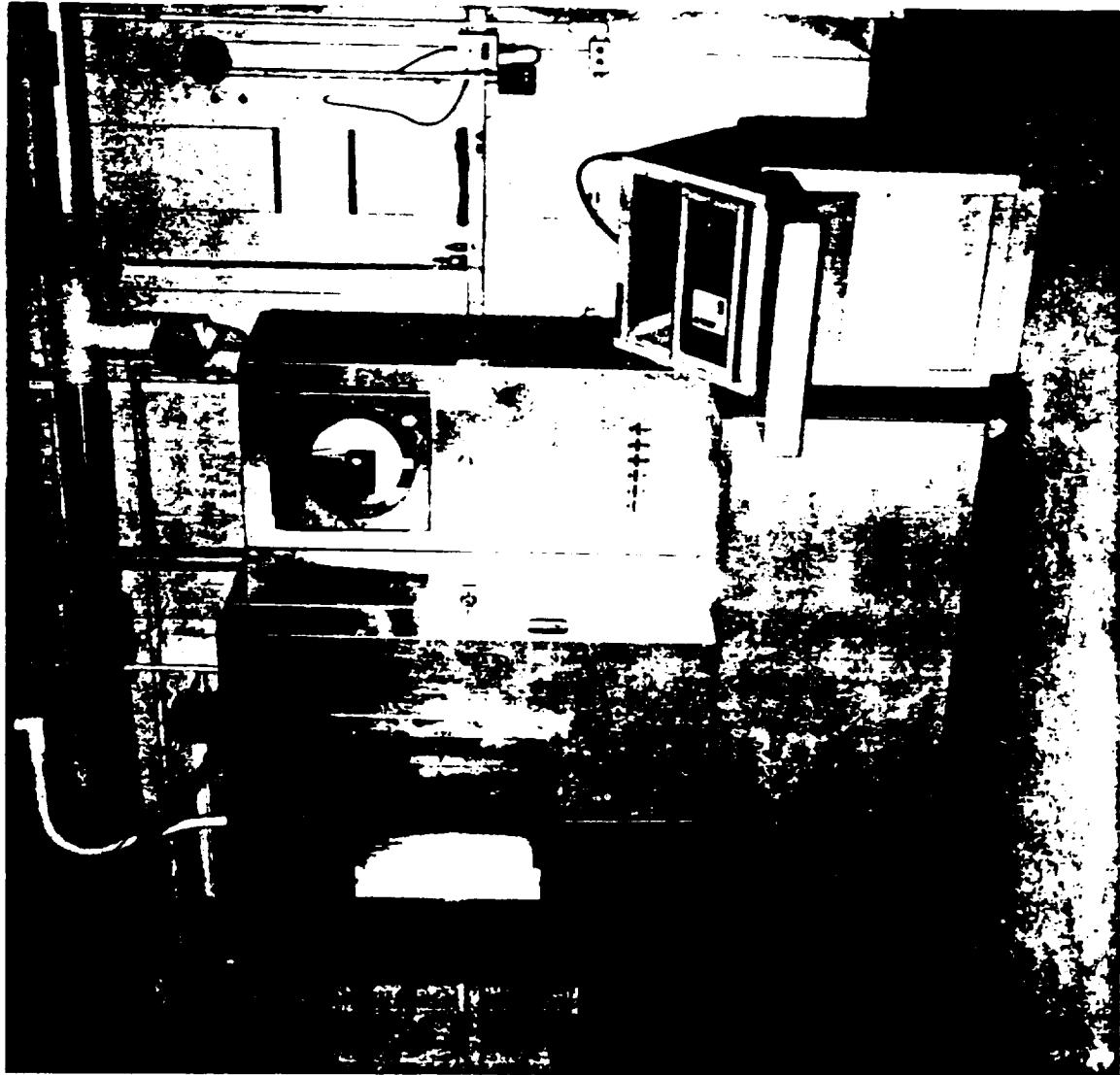


S84-31644

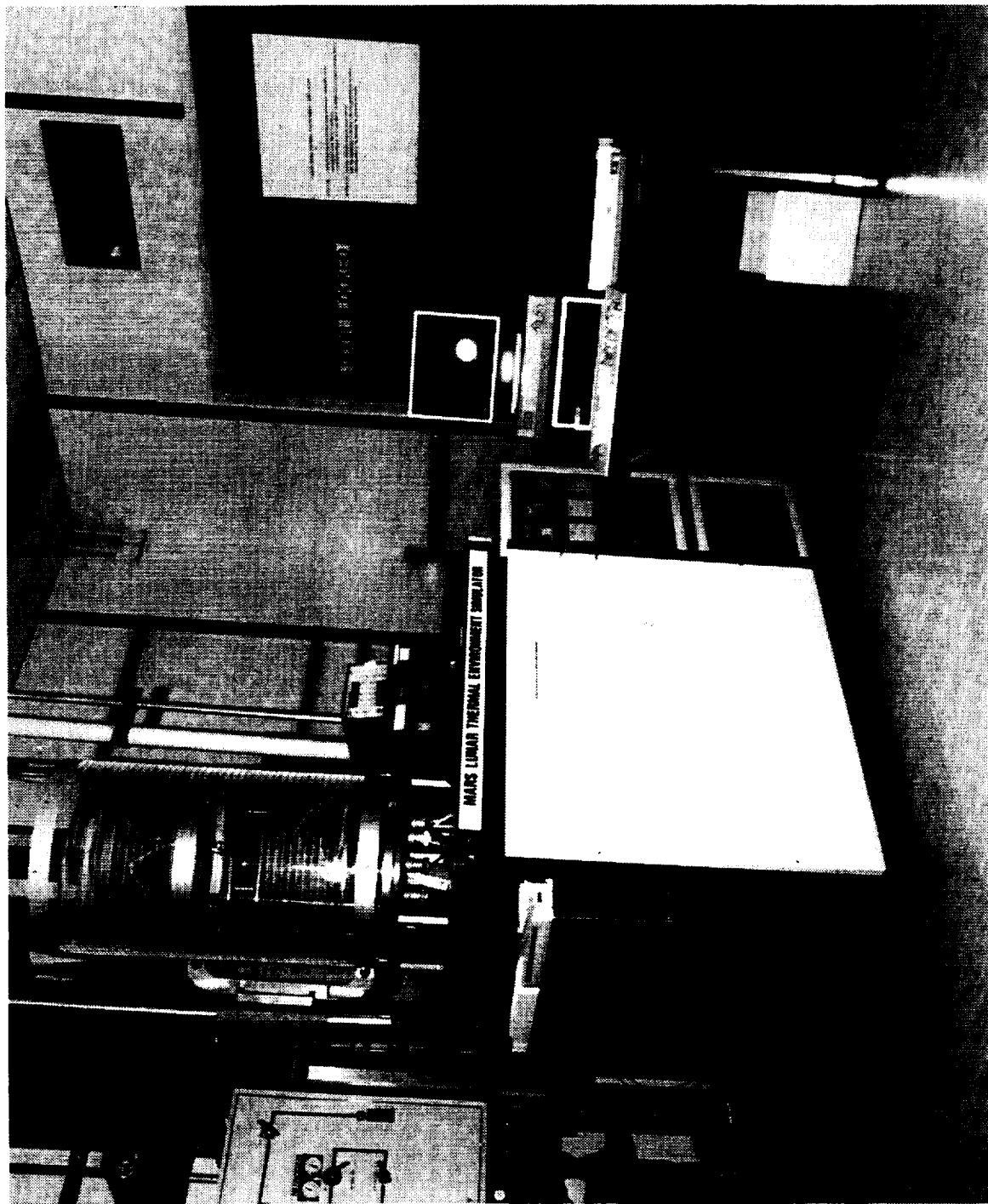
**CHAMBER R**



**CHAMBER T**

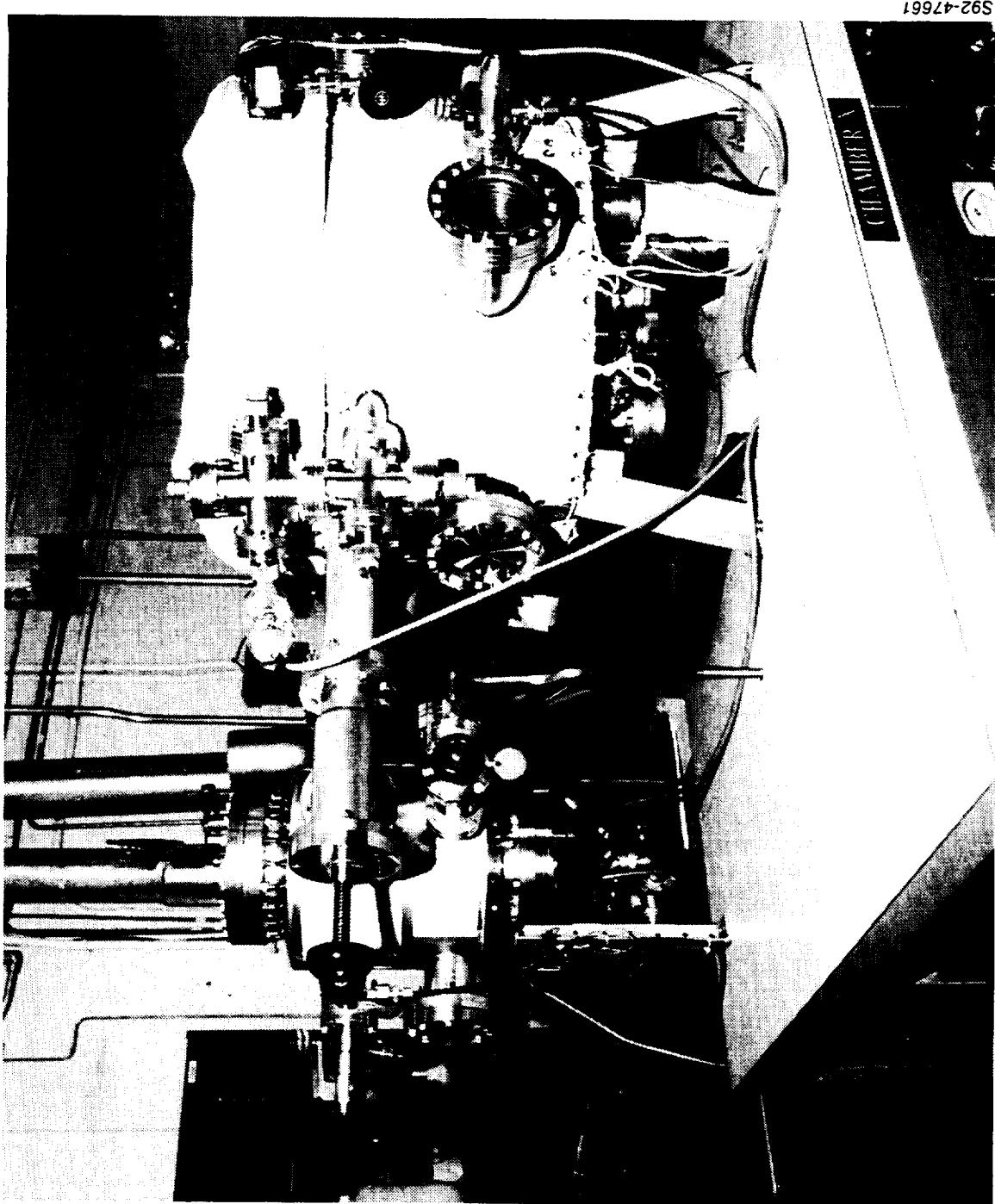


**CHAMBER V**



ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

CHAMBER X



S92-47661

## General Facility Specifications

### HYBRID REGENERATIVE WASTEWATER RECOVERY LABORATORY

LOCATION: Building 241

POINT OF CONTACT: Chief, Life Support Systems Branch,  
Code EC3, (713) 483-9208

STATUS: Active

YEAR BUILT: 1991

INITIAL COST: \$100k

REPLACEMENT COST: \$204k

USE: The test facilities in the Hybrid Regenerative Wastewater Recovery Lab are used to collect, measure, sample, and transport waste water. Wastewater can be collected from a urinal, handwash, shower, dishwasher, and laundry. The test facilities are used to support evaluation of advanced wastewater recovery techniques for Shuttle and advanced life support system research and development.

DESCRIPTION: The test facility includes the waste water collection and transport system and water analysis equipment. The waste water collection and transport system consists of a hot and cold deionized water supply, five collection interfaces (urinal, handwash, shower, dishwasher, and laundry), and an automated collection and transport subsystem. Water analysis systems provide the capability to sample test waters for total organic carbon and pH levels.

Test support utilities include 120 volts alternating current power and 482 633 pascals hot and cold deionized water.

DATA ACQUISITION: Data acquisition and waste water collection and transport system control are performed by a Hewlett Packard data acquisition system.

## **General Facility Specifications**

### **REGENERATIVE LIFE SUPPORT SYSTEM TEST BED (VARIABLE PRESSURE GROWTH CHAMBER, AMBIENT PRESSURE GROWTH CHAMBER)**

LOCATION: Building 7B

POINT OF CONTACT: Chief, Systems Test Branch, Code EC4,  
(713) 483-9208

STATUS: Active

YEAR BUILT: 1990

INITIAL COST: \$1,500k

REPLACEMENT COST: \$1,500k

substrate plant growth, lighting, cooling and ventilation, gas analysis and control, and the data acquisition, control, and recording system.

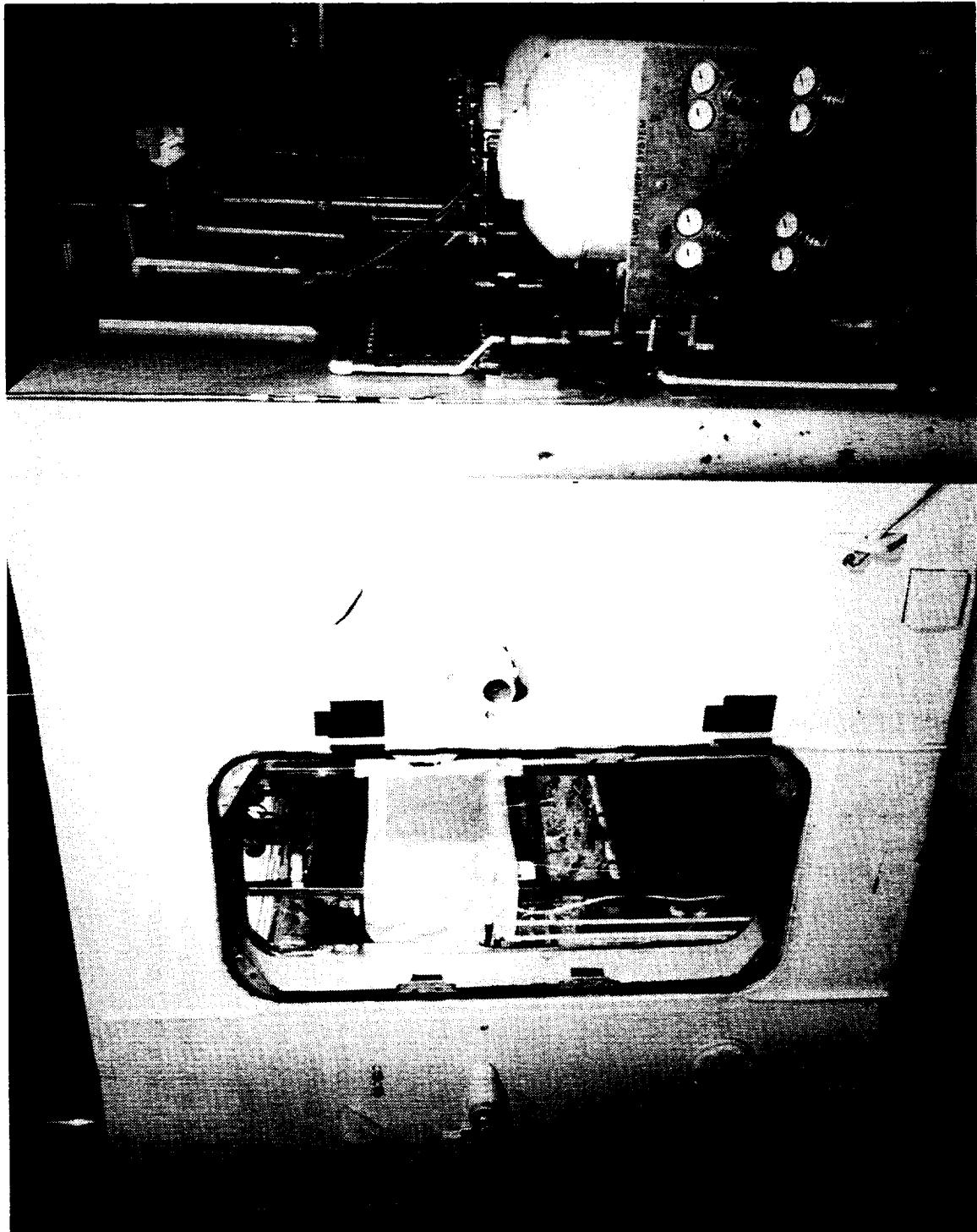
The Ambient Pressure Growth Chamber is a mirror image to the Variable Pressure Growth Chamber in terms of volume. The internal dimensions are approximately equal. This chamber is also equipped for plant growth with similar support systems. However, the fluid delivery system supports hydroponic plant growth. Cooling and ventilation, gas analysis and control, lighting, and data acquisition, control, and recording are provided in this chamber as well.

- Physical dimensions, both chambers: 2.7 meters wide by 2.4 meters height by 7.9 meters length, dual compartments of 4.3 meters and 3.6 meters, 53.2 meters volume
- Vacuum (variable chamber only): limited vacuum of seventy by  $10^{-3}$  pascals
- Access: 0.9 meter by 1.9 meter door at one end of main chamber and on airlock

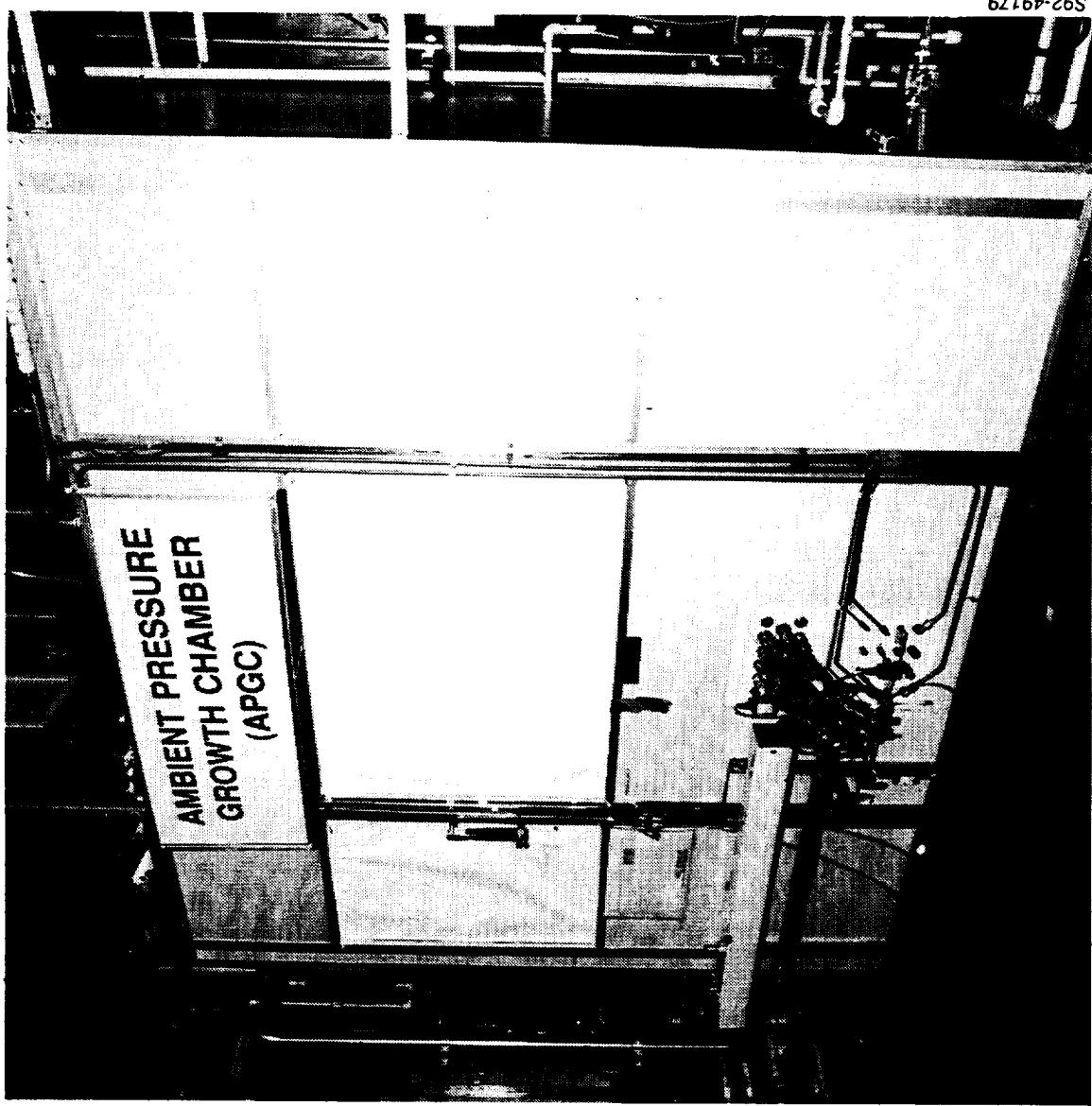
USE: The Variable Pressure Growth Chamber is a box chamber divided into two compartments with a door on each end. The chamber is a limited reduced pressure vessel. The interior is insulated to allow controlled variation in air humidity and temperature set points.

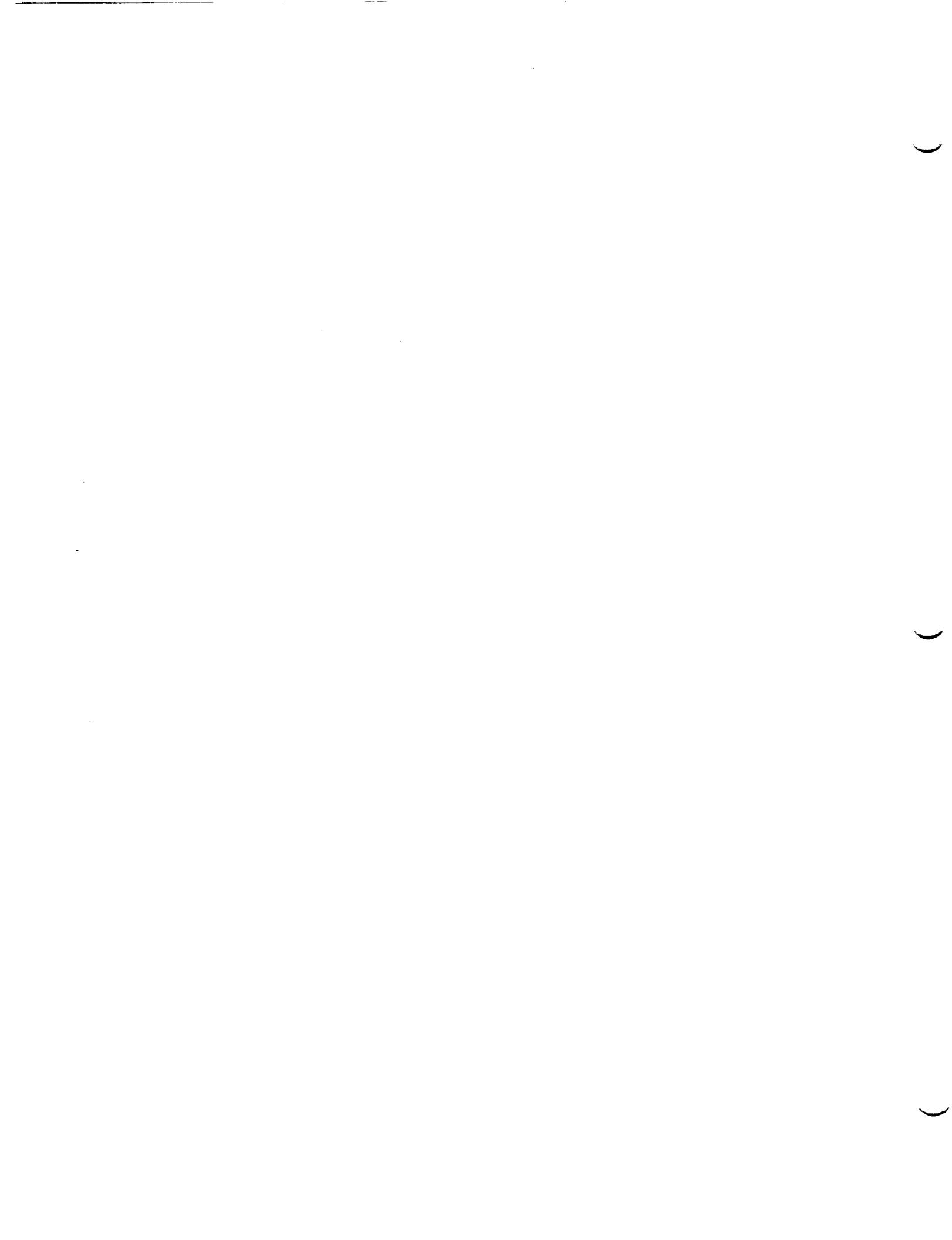
The chamber is outfitted with support systems for plant growth testing. Subsystems include a fluid delivery system for solid

VARIABLE PRESSURE GROWTH CHAMBER



**AMBIENT PRESSURE GROWTH CHAMBER**





CHAPTER 2  
TRACKING AND COMMUNICATIONS DIVISION (EE)

## Contents

FACILITY	PAGE	PAGE
Signal Processing Laboratory	2-65	2-65
Television Systems Laboratory	2-69	2-69
Text and Graphics Laboratory	2-73	2-73
Video Cassette Recorder System Laboratory	2-76	2-76

## Overview

The Tracking and Communications Division is responsible for systems design, interface, and performance analysis. It is responsible for design, development, test, and evaluation of hardware associated with space communications, tracking, radio frequency and optical sensing, landing aids, voice, television, command, modulation-demodulation, and allied subsystems ground support equipment. The division determines and implements techniques for secure modulation and radio frequency links for JSC programs.	2-11 2-16 2-21 2-23 2-26 2-34 2-35
In fulfilling these responsibilities, the Tracking and Communications Division establishes system concepts based on functional requirements. It implements the resulting subsystems with mission hardware which complies with JSC design, safety, security, reliability, and quality standards.	2-37 2-39 2-41 2-44 2-46 2-49 2-52 2-55 2-57 2-60 2-63
The division is also responsible for maintaining an advanced technical base, establishing and operating necessary test and laboratory facilities, and ensuring the engineering support necessary for providing technical direction to associated development and production contractors.	2-11 2-16 2-21 2-23 2-26 2-34 2-35 2-37 2-39 2-41 2-44 2-46 2-49 2-52 2-55 2-57 2-60 2-63

## General Facility Specifications ADVANCED AUDIO DEVELOPMENT LABORATORY

LOCATION: Building 44, Room 131

POINT OF CONTACT: Chief, Tracking and Communications  
Division, Code EE, (713) 483-2873

STATUS: Active

- Equipment for test and evaluation of audio and data modems and wide band audio encoders and associated ground support equipment
- Microcomputer development systems and computer-based schematic capture systems for use in designs and development of audio components and subsystems
- Specialized equipment for development and evaluation of highly sophisticated timer division multiplexing equipment for an Integrated Services Digital Network audio and data system

INITIAL COST: \$400k

REPLACEMENT COST: \$400k

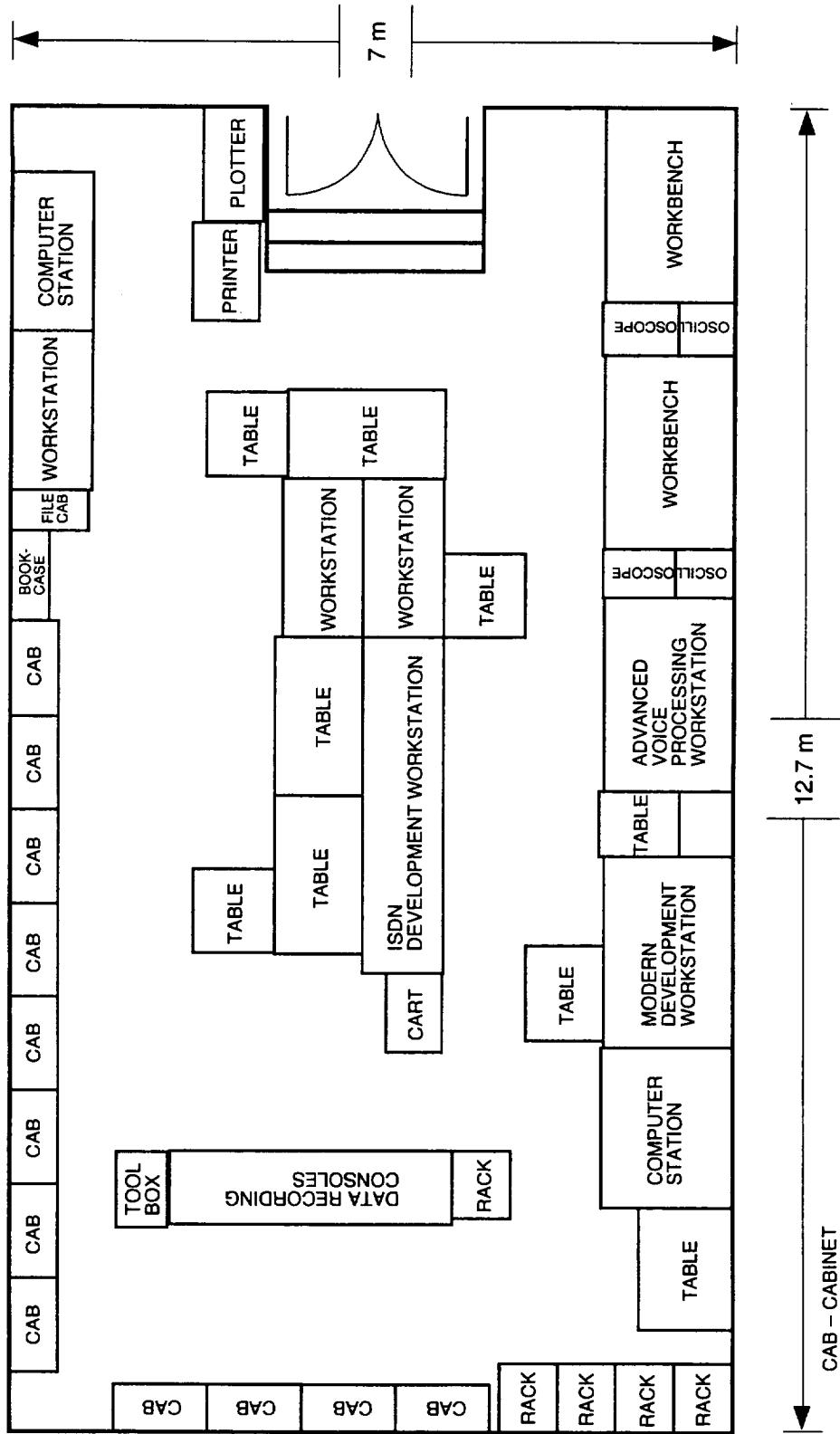
USE: The Advanced Audio Development Laboratory has capability for design, development, and test and verification of advanced audio equipment and systems, including the design and development of audio and data modems, wide band audio encoders, and an Integrated Services Digital Network for both audio and data.

DESCRIPTION: This facility functions as a development and testing area for data advanced audio equipment and systems.

DATA ACQUISITION: Manual acquisition is made from test instrumentation, oscilloscopes, spectrum analyzers, logic analyzers, etc.

## ADVANCED AUDIO DEVELOPMENT LABORATORY

ROOM 131



## General Facility Specifications

### ADVANCED VOICE PROCESSING LABORATORY

LOCATION: Building 44, Rooms 242 and 245

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$15k

REPLACEMENT COST: \$300k

USE: The Advanced Voice Processing Laboratory has capability to support development, analysis, and testing of voice synthesis and automatic speech recognition devices.

DESCRIPTION: This laboratory is utilized for development, analysis, and testing of voice processing, voice synthesis, and voice recognition systems and devices. Utilities for the development of specialized microprocessor-based systems are also available. Prototype and flight systems to control Space Shuttle onboard subsystems (e.g., the closed-circuit television system) by voice commands are being constructed as well as prototype systems for Space Station Freedom.

Primary laboratory activity is the design, fabrication, and testing of the flight voice command system. The following is being accomplished to support this project:

- Qualification and flight hardware is being fabricated, and flight software is being developed.
- Evaluation of various speech recognizers and synthesizers, as they become available, is another laboratory function. New technologies are evaluated and, if useful, integrated into developing systems.

The Advanced Voice Processing Laboratory is also equipped with digital voice processing capability. Speech analysis plots available include amplitude versus frequency versus time (third dimension shown in color), speech energy versus time, and cepstrum (pitch tracking) versus time. Digital tape recording and playback is also available.

DATA ACQUISITION: Manual data acquisition is made from test instrumentation, spectrum analyzers, logic analyzers, digital oscilloscopes, and digital tape recordings.

## **General Facility Specifications**

### **ANECHOIC CHAMBER FACILITY**

**LOCATION:** Building 14, Room 133

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1965 (major modification: 1987-91)

**INITIAL COST:** \$2,476k (not including construction of facility)

**REPLACEMENT COST:** \$8,000k (not including construction of facility)

**USE:** The Anechoic Chamber Facility is used to evaluate the electromagnetic radiation properties of antennae and other radiating objects. This facility is able to accommodate large structures and provides a reflection- and interference-free environment for testing due to its shielding and microwave absorber lining. Far-field radiation distribution patterns, near-field antenna measurements, and radar cross-section measurements are routinely performed in this facility. The current frequency range capabilities for far-field tests are one to forty gigahertz. For near-field tests, the frequency range is restricted to one to 26.5 gigahertz.

**DESCRIPTION:** The Anechoic Chamber is designed as a modified, flared wave guide horn with microwave absorbing materials lining the inner surfaces. This design provides an

optimal indoor far-field testing environment. A device-under-test located at the flared end is illuminated uniformly by a radiating source located at the tapered end. The overall length of the Anechoic Chamber is 45.72 meters. The width and height dimensions at the flared end are 15.24 meters by 15.24 meters. A movable wall exists at this end to allow the entry of large test articles and heavy machinery needed for test preparation. A rectangular shaped "testing area" measuring 12.2 meters wide, 18.3 meters long, and having a vertical clearance of 11.9 meters exists at the flared end of the Anechoic Chamber. The level floor space in the testing area is approximately 232 square meters. The microwave absorber on the floor in this area is not bonded to allow for flexible floor layouts. A large three-axis positioner with single or twin model towers is used to position test objects during far-field testing. It is stationed in the testing area approximately 36.6 meters from the tapered end of the Anechoic Chamber. The positioner is capable of holding and rotating objects that are 7.6 meters long, 6.1 meters in diameter, and weighing 454 kilograms.

The recent (1991) addition of a near-field measurement facility within the Anechoic Chamber expanded the testing capabilities of this facility. This feature provides a means of analyzing radiating structures in cases where far-field measurements are impractical due to range length requirements. The design for the near-field facility is based on the rectangular near-field measurement technique developed by Georgia Tech. It is capable of acquiring data over a horizontal scan plane. The support structure for the near-field facility places the scan plane

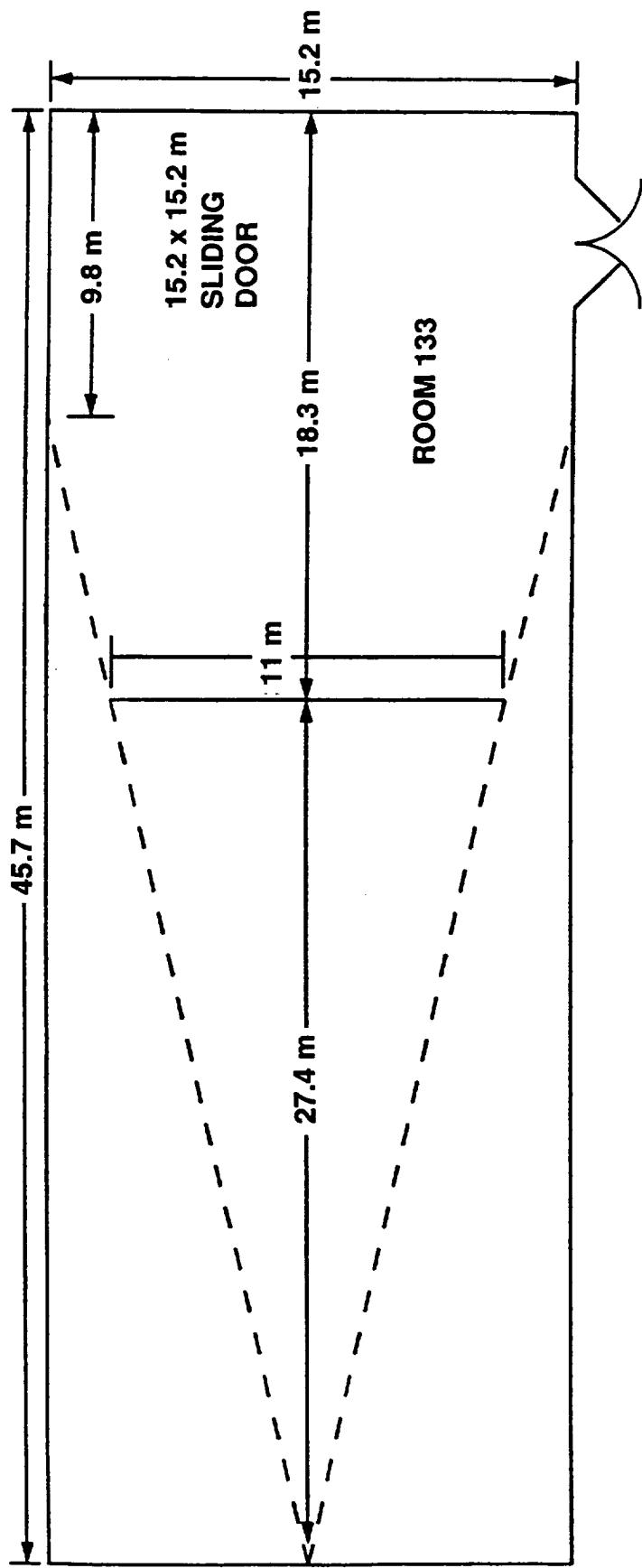
and all mechanical components 11.9 meters above the testing area in the Anechoic Chamber. Near-field scanning is accomplished by east-west movement of a large translation beam which spans the width of the Anechoic Chamber and by north-south movement of an electromagnetic probe contained within the translation beam. Test objects are positioned beneath the scan plane with the support of an 88 964-newton hydraulic lift which is built into the floor of the Anechoic Chamber. The lift can raise large test objects as high as 9.14 meters above the floor. All visible surfaces of the near-field facility are concealed with microwave absorbing materials.

Two personnel access doors, one single and one double, provide floor-level entry to the Anechoic Chamber. A third door, located in the adjacent third-floor Antenna Laboratory, provides immediate access to the near-field measurement facility. High-level lighting provides adequate structure and floor illumination inside the Anechoic Chamber. A 131 888 watt capacity air-conditioning unit provides a satisfactory working environment. A closed-circuit television camera is mounted inside to allow external viewing of tests in progress. Power receptacles for 120 volt alternating current, single phase, and twenty-eight volt direct current are provided inside the Anechoic Chamber. Three cable penetration panels are provided along the north wall to allow the capability for using external circuitry without violating shielding integrity. The electromagnetic shielding for the Anechoic Chamber is specified for minus one hundred decibels from ten kilohertz to ten gigahertz. The microwave absorber used to line the inside of the Anechoic Chamber is specified for minus thirty decibels at one gigahertz and minus fifty decibels at eighteen gigahertz and above.

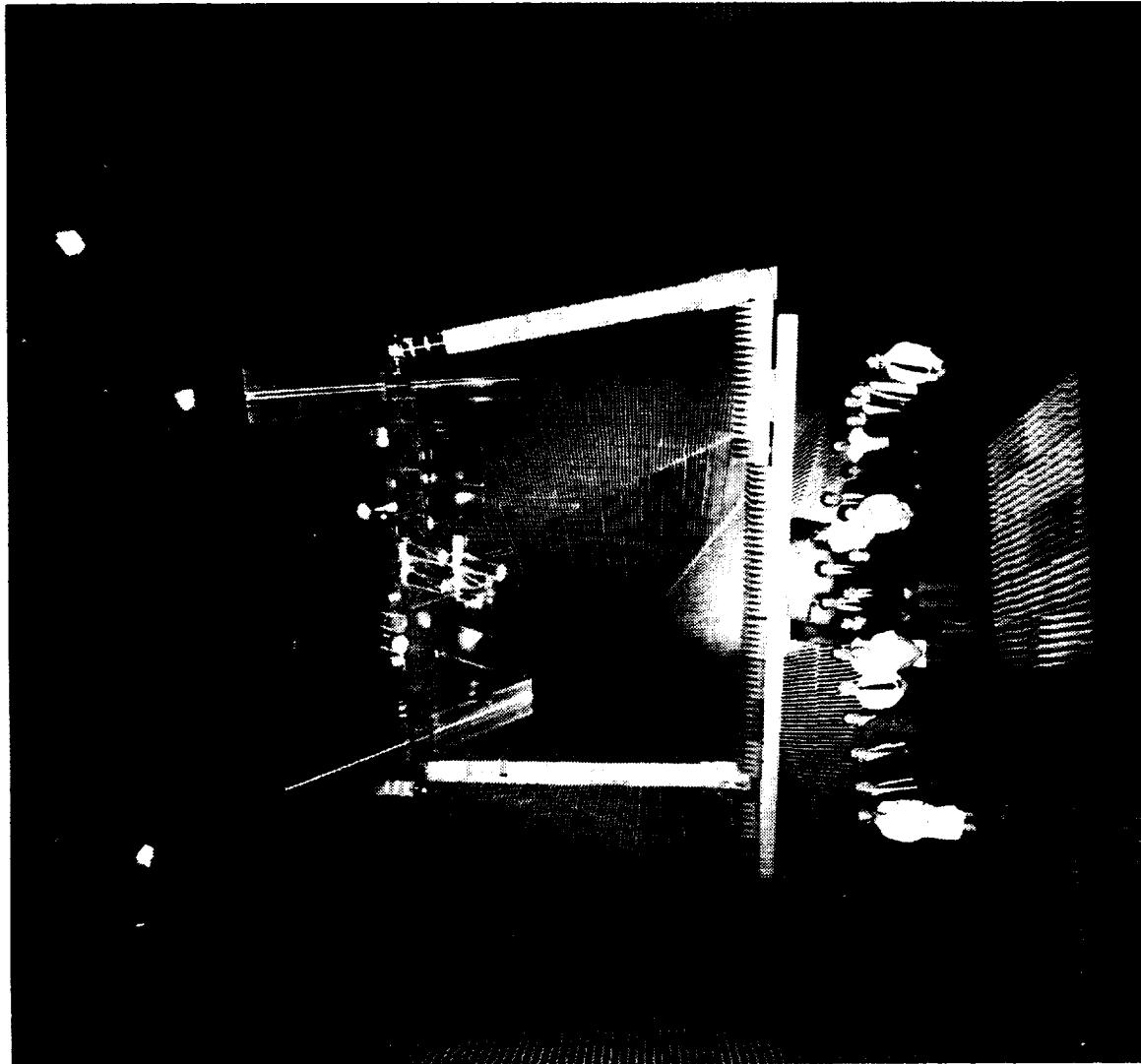
Other rooms used in support of the Anechoic Chamber include the high bay room, located adjacent to the Anechoic Chamber on the ground floor. This room is used for storing test equipment and structures. The high bay contains an 88 964-newton bridge crane which is used for handling large test items. The data acquisition instrumentation, the positioner controls, and the computer workstation associated with the far-field function of the Anechoic Chamber are located in a shielded room located in the high bay. Below the tapered end of the Anechoic Chamber is an 8.36-square-meter, shielded cubical which is used for installing transmitting antennas in preparation for far-field testing. The Antenna Laboratory located on the third floor and adjacent to the Anechoic Chamber houses the data acquisition system, laser metrology electronics, and motion controls for the near-field measurement facility.

DATA ACQUISITION: Both manual and automated test procedures are in place for performing far-field and radar cross-section measurements. A variety of signal generators, receivers, analyzers, and chart recorders are available for manual testing. Automated measurements are performed with the Flam & Russell FR8003 Automated Radar Cross Section and Antenna Measurement System. The system software and acquired data are maintained on a Hewlett Packard 9000/360 UNIX workstation computer. The control software for performing automated near-field antenna measurements is maintained on a Hewlett Packard 1000/A900 computer system.

## ANECHOIC CHAMBER FACILITY FLOOR PLAN



**ANECHOIC CHAMBER**



S91-52534

## **General Facility Specifications**

### **COMMUNICATION SYSTEMS DEVELOPMENT LABORATORY**

**LOCATION:** Building 14, Room 131

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** \$250k (not including construction of the facility)

**REPLACEMENT COST:** \$2,000k (not including construction of the facility)

**USE:** The Communication Systems Development Laboratory has capability for the design, development, breadboard fabrication test, and evaluation of communication components and systems for spaceflight vehicles.

**DESCRIPTION:** This facility comprises one room occupying approximately 89.2 square meters of floor area. The room contains workbenches, tools, parts, and test consoles necessary for fabrication and testing of breadboards and for component and system level tests.

The current activities in this laboratory are the design and implementation of an ultrahigh frequency communications system for EVA astronauts for the Shuttle and Space Station Freedom programs, a digital demodulator for the Shuttle

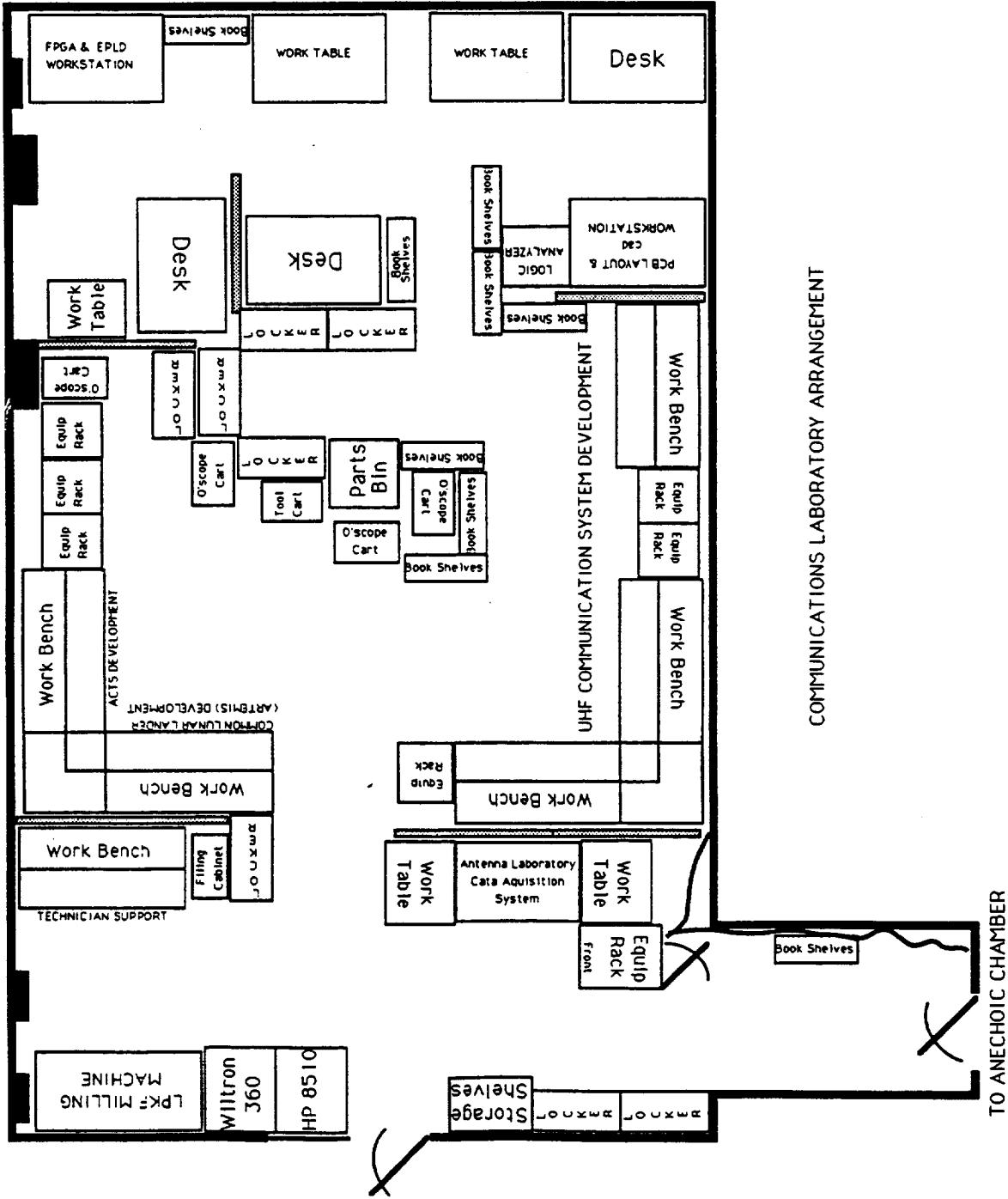
extended range payload communication system, a costas loop demodulator for the Space Station assembly contingency subsystem, an antenna sampling system for the common lunar lander, and a spread spectrum transceiver for the tracking and data relay satellite.

Major equipment items available in the facility are the following: synthesized signal and function generators, power meters, a spectrum analyzer, a Vector modulation analyzer, a network analyzer, a bit error rate detector, a wireless communication testbed, direct current power supplies and meters, and oscilloscopes. Other components and breadboards in the laboratory have provided the capability to simulate scenarios in analog and digital communication systems to investigate various problems. This capability includes the ability to produce offset quadrature shift key modulation of several Ku-band carriers simultaneously, for use in testing adjacent channel interference, intermodulation distortion, and other effects peculiar to multiple access systems.

Design projects in the laboratory have provided the capability to test certain synchronous communication demodulator concepts. These include a quadrupling loop carrier extractor, a costas loop carrier extractor, and a squaring loop bit timing extractor.

**DATA ACQUISITION:** Automated acquisition from a Hewlett Packard Interface Bus enables a complete instrumentation test run with a Hewlett Packard Controller.

## COMMUNICATION SYSTEMS DEVELOPMENT LABORATORY FLOOR PLAN



## **General Facility Specifications**

### **COMMUNICATION SYSTEMS SIMULATION LABORATORY**

**LOCATION:** Building 44, Rooms 237 and 237A

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1984

**INITIAL COST:** \$100K

**REPLACEMENT COST:** \$1.9M

**USE:** The Communication Systems Simulation Laboratory is a computer laboratory which simulates space communication systems for the Space Station, the Shuttle, and advanced programs. There are two basic simulators which are used in this laboratory: a communication signal analysis simulator called the Block-Oriented System Simulator and a radio frequency coverage simulator called the Dynamic Environment Communications Analysis Testbed. These simulators are used for system design, design verification and optimization, derivation of system level specifications, flight hardware test result predictions and anomaly investigations, operational performance predictions, and operational anomaly investigations.

**DESCRIPTION:** The Communication Systems Simulation Laboratory is a computer laboratory which simulates space

communication systems for the Space Station, the Shuttle, and advanced programs. The laboratory consists of the following hardware: VAX 6310 mainframe, four VAX 3100 workstations, a VAX 3500 workstation, a VAX 3600 file server, a VAX II workstation, a Silicon Graphics IRIS 3-D Graphics workstation, and a Sun 4/260 workstation. The two basic simulators, mentioned above, are used in the laboratory.

Radio frequency coverage analysis is the computation of communication link performance as a function of vehicle and planet dynamics, antenna dynamics and patterns, vehicle structures, interferers, and link parameters. Communication link performance includes calculation of the range, range rate, and pointing vector from the transmitting antenna to the receiving antenna. Using these parameters and the initial link parameters, certain degradations due to the following can be determined: space loss, Doppler effect, antenna obscuration, multipath degradation, and external interference. The received power can be calculated along with the ratio of received power to interference if interferers are modeled. Critical to the performance of a communications link is the location of both the transmitting and receiving antennae. Effects of physical obscuration of an antenna by the vehicle structures or planets on communications can range from minor attenuation of the signal to complete loss of the link. By analyzing the effect of obscuration on the link, the optimum placement, number, and orientation of the antennae may be determined.

The Dynamic Environment Communications Analysis Testbed is a simulation tool used for the rapid analysis of radio frequency coverage. This testbed is used for the assessment of end-to-end radio frequency coverage, dynamic structural blockage, interference, and dynamic link performance. It is written in the C programming language and is very portable. It runs on VAX virtual memory system, Sun UNIX, and Cray computers. It has a user friendly X-Windows graphical user interface which is used to set up and run simulations. This user interface was written with Transportable Applications Environment. The Sun 4/260 workstation is also capable of 3-D graphics, and the Dynamic Environment Communications Analysis Testbed uses these graphics to display vehicles, line of sight of antennae, and antennae blockage.

The Block-Oriented System Simulator is a computer-aided communication signal analysis tool. It has a block-oriented graphical user interface, and Fortran simulation code is generated automatically from the block diagram. This simulator

is being used for both Shuttle and Space Station applications to calculate system performance on various communication links. It has an extensive database of communications models in addition to the basic building blocks from which new communications models may be built. These communication software models allow the user to design a communications link for observing the system in a manner closely analogous to that of building a hardware breadboard and making measurements in a hardware laboratory. The Block-Oriented System Simulator is ideally suited for performing system trades on communication systems without building expensive breadboards for each candidate design. As the communication system matures, a very detailed simulator can be achieved which can be used to support design optimization studies and to perform performance predictions for hardware tests and operational performance.

DATA ACQUISITION: Automated data acquisition performs the communication system simulations.

COMMUNICATIONS SYSTEMS SIMULATION LABORATORY WORKSTATIONS

ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

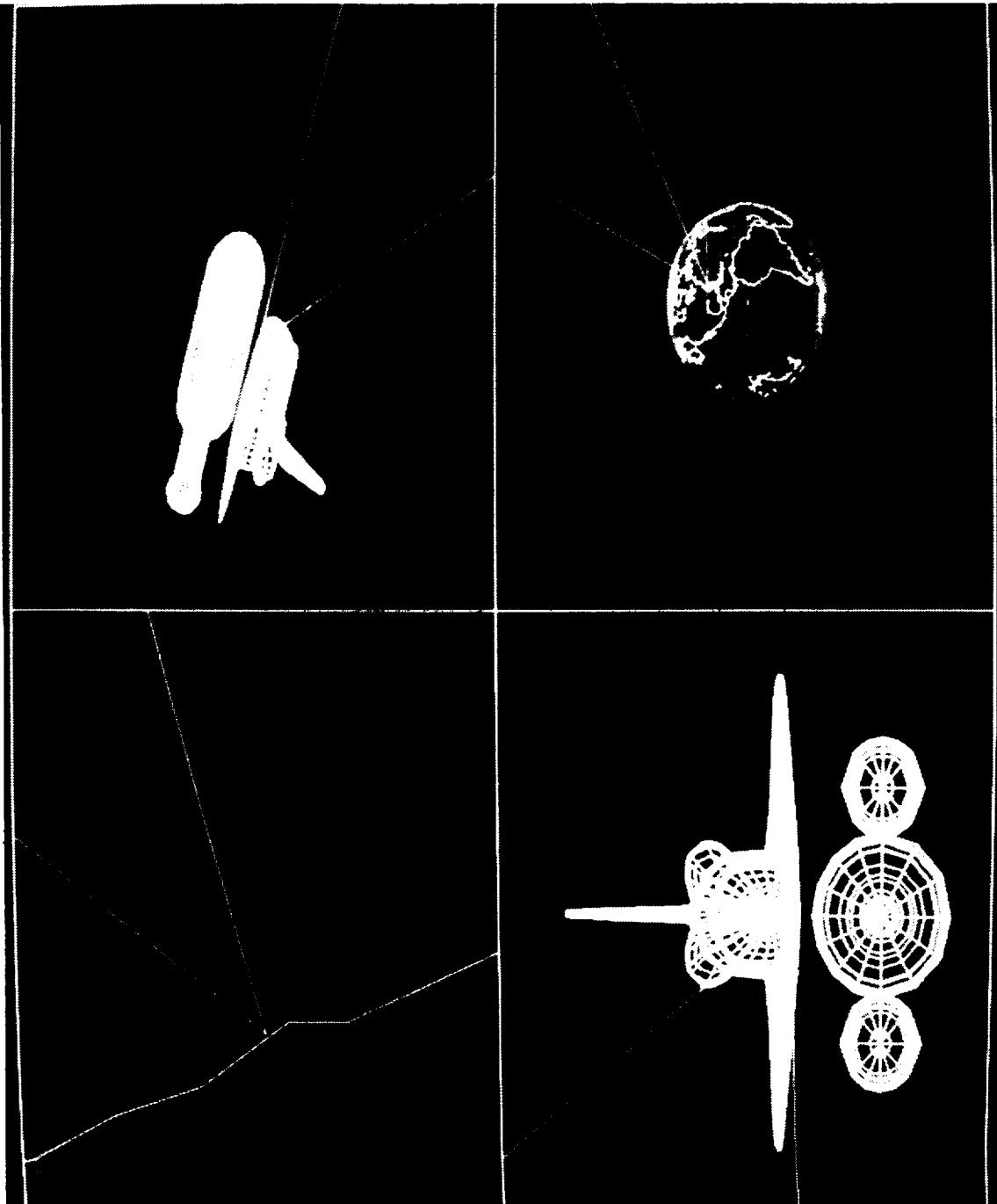
S89-43919



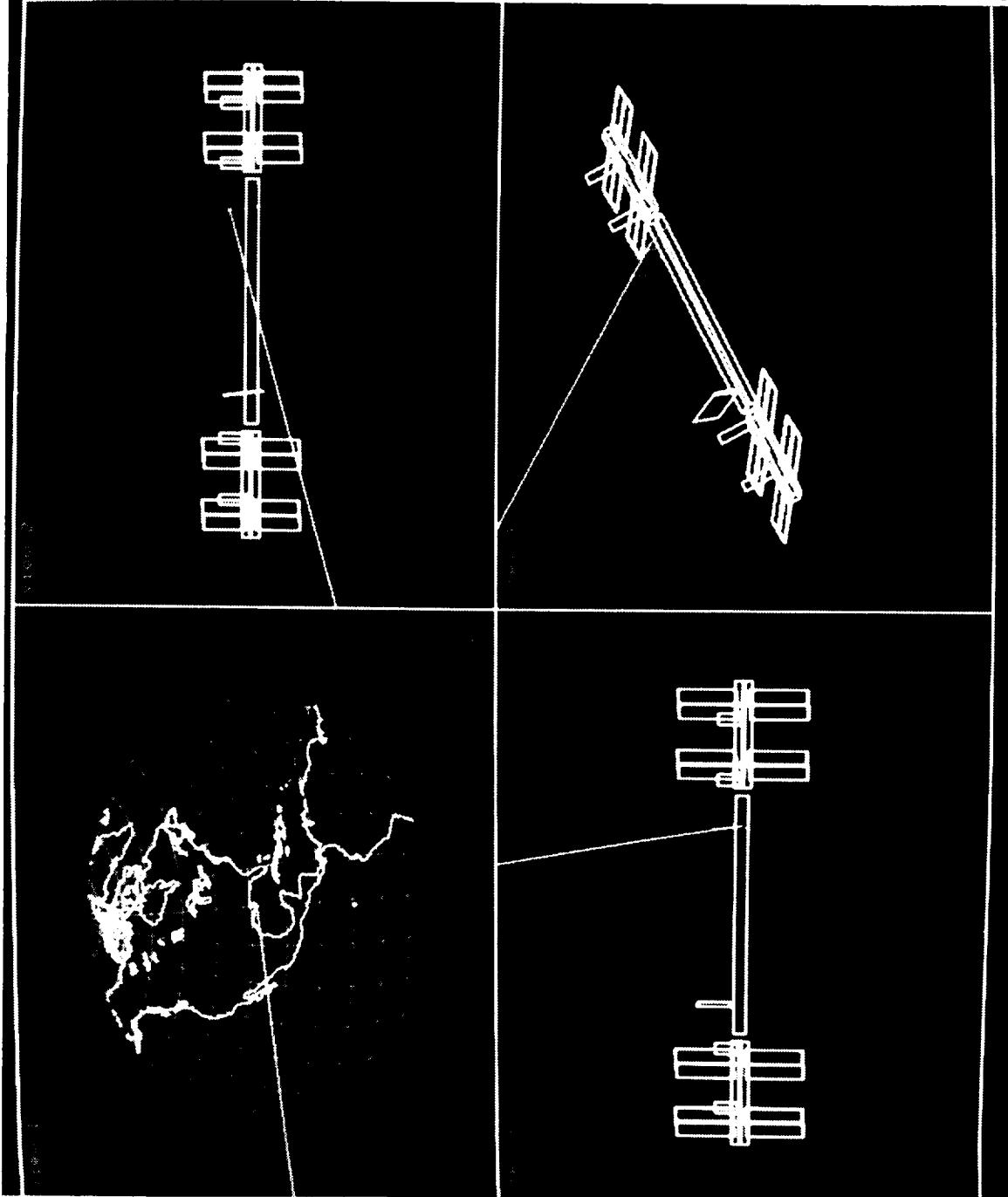
C-2

**COMMUNICATION SYSTEMS SIMULATION TESTBED/DYNAMIC ENVIRONMENT COMMUNICATIONS ANALYSIS  
TESTBED 3-D GRAPHICS OUTPUT OF SHUTTLE GPS FLIGHT EXPERIMENT RF COVERAGE**

S91-50486



**DECAT 3-D GRAPHICS OUTPUT OF SSF KU-BAND TDRS RF COVERAGE (THERMAL  
RADIATOR IS BLOCKING COVERAGE TO TDRS AT THIS INSTANT)**



## COMMUNICATIONS SOFTWARE DEVELOPMENT LABORATORY

### General Facility Specifications

LOCATION: Building 44, Rooms 219-221

POINT OF CONTACT: Chief, Tracking and Communications  
Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1986

INITIAL COST: \$200k

REPLACEMENT COST: \$500k

USE: The Communications Software Development Laboratory is used as testbed for the integration and interface verification of communication systems, as well as for the control of advanced prototype communication hardware and the development and evaluation of monitoring software prototypes. Communication subsystem simulators are being developed in software when necessary to generate and test candidate control and monitoring subsystem software demonstration packages.

DESCRIPTION: The Control and Monitoring Subsystem testbed was established in the Communications Software Development Laboratory to develop and evaluate candidate software systems in a hardware environment similar to that expected aboard Space Station Freedom. The Space Station Communications and Tracking software will monitor the performance and control the equipment of five other communications and tracking

subsystems: space-to-ground, space-to-space, television, audio, and ultrahigh frequency. The Communications and Tracking software will be hosted on two Standard Data Processors shared by other Space Station systems. These processors will interface with subsystem equipment via 1553B local buses.

The Communications and Tracking software functions are to initialize the Communications and Tracking subsystem Orbital Replacement Units; to monitor their status and performance data to detect faults; to isolate and recover from faults for the Assembly and Contingency Subsystem; to reconfigure Orbital Replacement Units per commands from the ground, crew, or Integrated Station Executive software; and to manage the Communications and Tracking directional antennae. Many of these software functions have not been written for use onboard spacecraft and therefore require prototyping of those candidate ideas that would perform the functions within the available processor resources. After the prototype software is coded and tested, an evaluation is made to determine if the approach is feasible for implementation as flight software. Test results and subsequent requirements are compiled into the Flight Systems Software Requirements document. The Flight Systems Software Requirements will be used as the sole source of requirements to generate the flight software.

An approach for automated resource and fault management to be done onboard the Space Station was developed and is called Fault Isolation by Bit Strings. This algorithm was

programmed in Ada and used a compiled fault network derived from previous efforts. Further reduction in computer resources aboard the Space Station, however, resulted in fault isolation and recovery procedures proposed for onboard software being moved to the ground where more resources are available for their operation.

Antenna Management is another major onboard software function that requires prototyping in the Communications Software Development Laboratory. The software will manage directional antennae through the Tracking and Data Relay Satellite System acquisition, handover, and the Zone of Exclusion. The Tracking and Data Relay Satellite System pointing vectors will be periodically generated by the Guidance, Navigation, and Control and Propulsion System and converted to the necessary gimbal angles for the Assembly and Contingency Subsystem and the Space-to-Ground Subsystem antennae. The first antenna management prototype software included display and control software for one SPARC workstation linked with a Silicon Graphics workstation to show how the Assembly and Contingency Subsystem and Space-to-Ground Subsystem antennae move during acquisition and handover maneuvers. More complex demonstration and simulation software is under development to increase the functionality and fidelity of the prototype software. This software is being codeveloped with the Communication Systems Simulation Laboratory. This laboratory will provide models of

the antenna assemblies and antenna structural blockage. The Communication Systems Simulation Laboratory and Communications Software Development Laboratory workstations will be linked by Ethernet to conduct integrated tests of the antenna management prototype software.

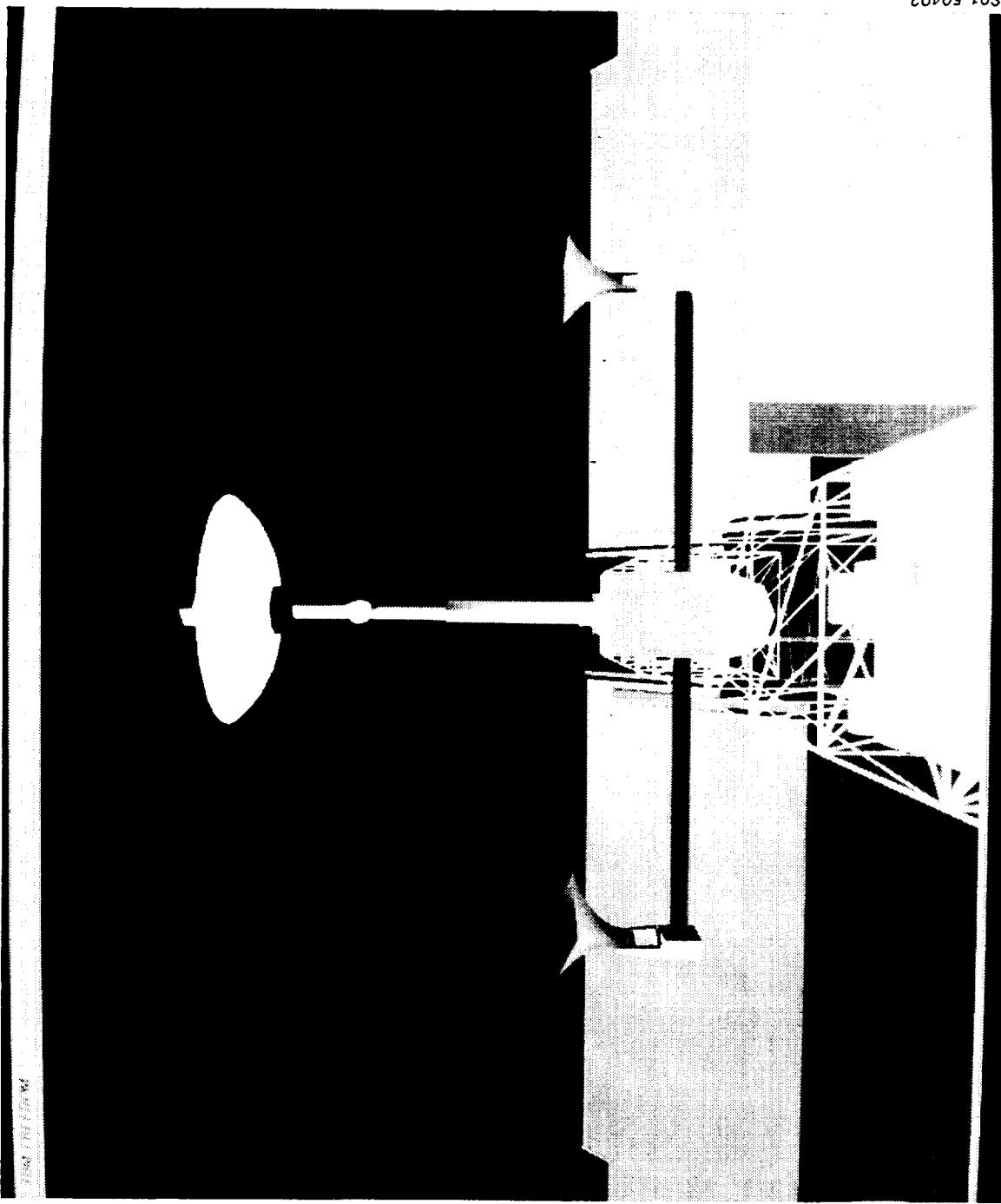
An essential ingredient for hardware and software integration testing is simulator software. Actual flight hardware will not be available when early prototype software concepts must be tested. Simulators were developed to output status data from the Orbital Replacement Units that indicate either good or healthy status. Current Communications Software Development Laboratory testbed simulators can accept and respond to commands received over a 1553B local bus and return status. These Orbital Replacement Unit simulators are hosted on inexpensive personal computers and are written in Ada. Future software development in the Development Laboratory will be based on this capability. Integrated testing of the Communications and Tracking subsystems with the early Communications and Tracking software may be performed using advanced Orbital Replacement Unit simulators developed in the Development Laboratory.

DATA ACQUISITION: Manual acquisition is made from test instrumentation, spectrum analyzers, strip charts, etc.

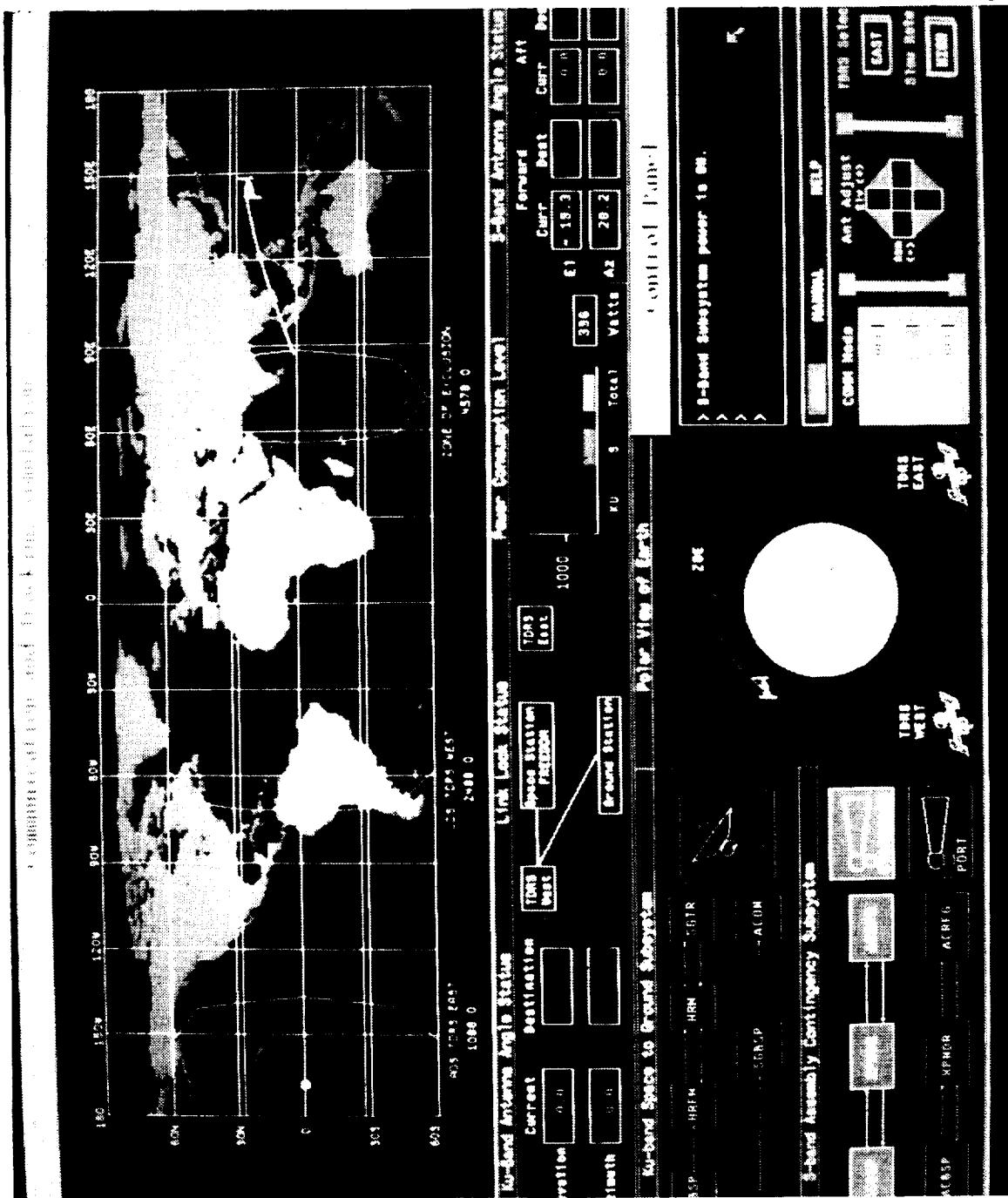
## COMMUNICATIONS SOFTWARE DEVELOPMENT LABORATORY WORKSTATIONS



**SIMULATION DISPLAY OF C&T ANTENNA SYSTEM STATUS AND SPACE STATION ORBIT**



# COMMUNICATIONS SOFTWARE DEPICTION OF ASSEMBLY/CONTINGENCY AND SPACE TO GROUND STEERABLE ANTENNAE MANAGEMENT



## **General Facility Specifications**

### **ELECTRICAL-ACOUSTICAL LABORATORY**

**LOCATION:** Building 44, Room 144

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1966

**INITIAL COST:** \$180k

**REPLACEMENT COST:** \$1,500k

quiet room provides a low acoustic noise environment for general headset and associated component testing.

**DESCRIPTION:** This facility, used to test and evaluate audio devices and analyze acoustic noise, has the following capabilities:

- Test and evaluation of headsets, earphones, microphones, speakers, voice processing circuits, and Space Shuttle audio system components, including development, acceptance, and qualification tests of flight and flight-related equipment
- Construction of breadboard versions of audio circuits to isolate design shortcomings and investigate design modifications
- Development of voice processing and multiplexing techniques to reduce audio and voice channel interface complexity
- Development of headsets and microphones for space suit communication systems
- Real-time signal analysis and assessment of voice communication
- Acoustic testing of spacecraft equipment to determine compliance with noise emission standards and to aid in acoustic noise troubleshooting and abatement

**USE:** The Electrical-Acoustical Laboratory contains a set of Shuttle audio system hardware and has the capability for the development and analysis of audio processing systems on a distributed system basis. The facility is currently being used for the Shuttle audio system support and for advanced audio device and systems development, test, and evaluation. The laboratory includes the audio reverberation chamber, audio anechoic chamber, and audio quiet room. The reverberation chamber is used to test audio devices under simulated launch and on-orbit noise. The audio anechoic chamber provides an echo-free environment for noise-sensitive acoustic testing. The audio

The following areas, listed with their capabilities, comprise the Audio Systems Laboratory:

- Reverberation chamber
  - Diffused sound field environment
  - Launch and on-orbit noise simulation
  - Measurement of acoustic noise of hardware
  - Voice recognition testing
- Quiet room and test control area
  - Headset and audio components test facility
  - Computer-aided design
- Anechoic Chamber
  - Headset testing
  - Voice recognition testing
  - Echo-free acoustic environment
  - Measurement of acoustic noise of hardware
- Thermal test chamber
  - Headset and audio hardware thermal acceptance and qualification testing
  - Temperature range of minus seventy degrees centigrade to plus 170 degrees centigrade

The following specialized equipment is available in the laboratory:

- High-resolution, digital-based, fast-Fourier, transform real-time analyzer (resolution of four thousand spectral lines, frequency band of zero to twenty kilohertz, seventy decibels input range, ten thousand input sample memory)
- One-third octave, digital-based, Fourier transform real-time analyzer (resolution of forty-two channels, frequency band of two to sixteen kilohertz, one hundred decibels input range)
- Hybrid real-time analyzer (resolution of four hundred spectral lines, frequency band of zero to twenty kilohertz, fifty decibels input range)
- One-third octave filter sets (resolution of thirty channels, frequency band of twenty-five hertz to twenty kilohertz, plus or minus twenty decibels amplitude control)
- High resolution audio measurement microphone-amplifier systems

DATA ACQUISITION: Manual acquisition is made from test instrumentation, spectrum analyzers, strip charts, logic analyzers, digital oscilloscopes, etc.

## **ELECTROMAGNETIC COMPATIBILITY AND ELECTROMAGNETIC INTERFERENCE TESTING LABORATORY**

### **General Facility Specifications**

**LOCATION:** Building 14, Room 133D

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** \$150K (not including construction of facility)

**REPLACEMENT COST:** \$500k (not including construction of facility)

**USE:** The Electromagnetic Compatibility and Electromagnetic Interference Testing Laboratory has capability for electromagnetic compatibility and electromagnetic interference evaluation and certification testing of the following crew support equipment, flight equipment, and ground support equipment: communications equipment, instrumentation equipment, biomedical equipment, guidance and navigation equipment, computation equipment, and so on. This facility provides support for all electrical and electronic equipment center-wide, as well as providing electromagnetic interference support for United States Air Force equipment.

**DESCRIPTION:** Electromagnetic compatibility and electromagnetic interference testing are collocated in Room

133, hence known as the Electromagnetic Compatibility and Electromagnetic Interference Testing Laboratory. The electromagnetic compatibility area houses three shielded enclosures occupying approximately 360 square feet of floor space. The enclosures provide radio frequency isolation from the facility ambient levels, allowing measurement to current electromagnetic compatibility specification requirements. Typical shielding effectiveness of the enclosures is one hundred decibels in a frequency range of fourteen kilohertz to ten gigahertz. The larger enclosure houses the test samples and antennae, while the two smaller enclosures house the automated electromagnetic compatibility test equipment.

The primary laboratory activity at the present time is the electromagnetic compatibility evaluation and certification of flight hardware and ground support equipment. Testing of facility shielding effectiveness at other JSC facilities is also performed using Electromagnetic Compatibility Laboratory equipment. This facility provides support for all electrical and electronic systems and facilities center wide.

Major items of equipment are as follows: The Hewlett Packard 8568 automatic spectrum analyzer system consists of the Hewlett Packard 8566B spectrum analyzer, the Hewlett Packard Laser II printer, the Hewlett Packard 7470 multipen plotter, the Hewlett Packard 85685A radio frequency preselector, and the Hewlett Packard 9000/300 series desktop computer.

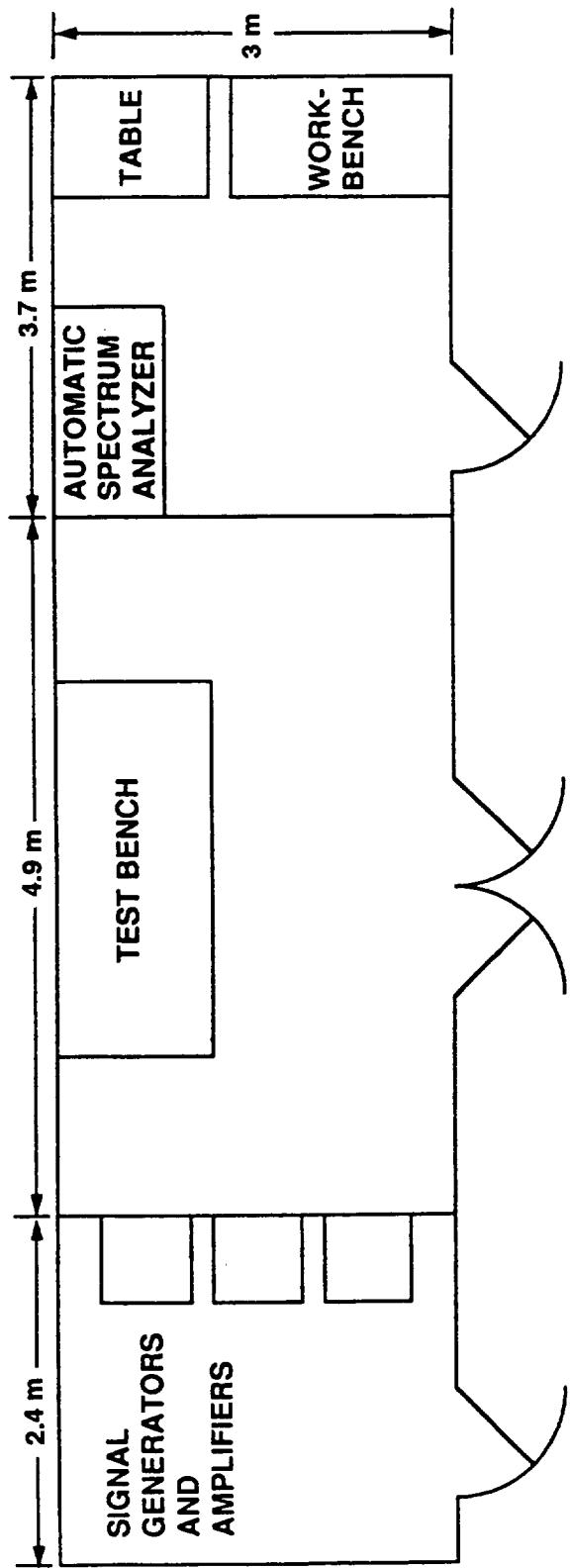
The spectrum analyzer is capable of spectrum analysis over a range of thirty hertz to twenty-two gigahertz. All spectrum analyzer controls are completely accessible from the computer keyboard. Measured data may be displayed on the computer cathode-ray tube, or the printer and plotter, and stored on computer disk.

Also available in the Electromagnetic Compatibility Test Laboratory is a series of synthesized signal generators capable of covering a frequency range of ten hertz to twenty-six gigahertz. In the frequency range of fourteen kilohertz to eighteen gigahertz, radio frequency power amplifiers are available to provide twenty watts of output power. This equipment is used to perform susceptibility testing on flight hardware.

A complete line of general purpose, ancillary test equipment (power supplies, oscilloscopes, power meters, voltmeters, etc.) is available for test support.

**DATA ACQUISITION:** Data are acquired in the Electromagnetic Interference Laboratory by both manual and automatic means. During interference emissions tests data are acquired automatically by the Hewlett Packard 8568 Spectrum Analyzer System and stored on the computer for future record and analysis. Data acquisition and storage techniques during interference susceptibility tests vary depending upon the device under test. Many devices can be monitored by means of a computer while others rely on simple oscilloscope measurements. In all cases interference susceptibility testing involves manual application of the required signals and human observation of out of tolerance conditions.

**ELECTROMAGNETIC COMPATIBILITY AND ELECTROMAGNETIC INTERFERENCE  
TESTING LABORATORY FLOOR PLAN**



## General Facility Specifications

### ELECTRONIC SYSTEMS TEST LABORATORY

LOCATION: Building 44, Rooms 117, 120-127, 131, 136 and 144B

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$3,200k

REPLACEMENT COST: \$85,000k

USE: The Electronic Systems Test Laboratory has capability for radio frequency systems testing of spacecraft communications systems with external elements in a realistic, controlled, calibrated radio frequency environment, space-to-space and space-to-ground communication systems end-to-end testing for design verification, radio frequency compatibility, and performance evaluation. Flight and operational equivalent equipment are utilized to insure fidelity of results.

DESCRIPTION: The JSC Electronic Systems Test Laboratory provides NASA with a unique, major ground test facility. This is the only NASA location where space vehicle communications equipment can be interfaced with its external counterparts (ground stations, relay satellites, etc.) in a controlled, calibrated radio frequency environment to accurately, quantitatively

evaluate end-to-end performance under realistic mission radio frequency conditions. The facility employs actual equipment for the various elements of the communication systems to avoid uncertainties and inaccuracies that would result from the use of simulators. Utilization of this facility throughout the design, development, and operational program phases provides verification that the design techniques, hardware implementation, and operational configuration of all items in the communication system will provide the performance required to meet mission requirements.

Located in Building 44 at JSC, the Electronic Systems Test Laboratory is an \$85 million, 1473 square meters facility. Figure 1 depicts the laboratory's floor plan. It includes five radio-frequency-shielded enclosures that provide radio frequency isolation between transmitting and receiving systems. Additionally, the facility has the capability to transmit and receive radio frequency signals from an orbiting Tracking and Data Relay Satellite System via S-band and Ku-band antenna systems. The 4.9 meter S-band antenna depicted in Figure 2 is located on the rooftop of Building 44. The orbiter Ku-band antenna (Figure 3) is housed in a 4.3 meter radome in the laboratory's radome facility (Figure 4). The larger 6.7 meter radome will eventually house the Space Station antennae. Included in the facility instrumentation are the radio frequency and data systems portion of both the Ground Spacecraft Tracking and Data Network and Tracking and the Data Relay Satellite System ground stations and a Tracking and Data Relay Satellite System satellite (See Table 1). Special instrumentation

includes a VAX 11/785, an high-speed APTEC input and output processor, data delay units, frame synchronization strategy detectors, bit error rate detectors, dynamic Doppler simulator, an automated data recording and graphics system, data generators, recorders, and precision space loss simulators. Hard-line, fiber optic and radio frequency interfaces are provided to the Building 16 Shuttle Avionics Integration Laboratory and Building 30 Mission Control Center.

Tests are performed by operating the space, ground, and relay satellite communication systems simultaneously in a manner which accurately reflects actual space-to-space and space-to-ground mission configurations. With the appropriate radio frequency links established, the effect on system performance is evaluated for such radio frequency design parameters as modulation type, modulation index, multiplexing methods, channel bandwidths, etc., with realistic mission conditions of Doppler frequency shift, path loss, and potentially interfering radio frequency signals. Quantitative measurements of the communication system acquisition, range, and data handling capability are made in the end-to-end configuration to establish that it meets mission requirements.

The Electronic Systems Test Laboratory provides accurate, reliable test data during all program phases from conceptual design through hardware development and extending into operations. During the conceptual design phase, advanced communications techniques, such as novel modulation schemes, are thoroughly tested in a systems environment. As prototype hardware is being developed, quantitative tests are

performed to evaluate this equipment in a controlled, calibrated, realistic, integrated systems radio frequency environment. This environment includes both planned and potentially interfering radio links to external communication system elements. To avoid costly redesign, these tests are initiated early in the development cycle. At the completion of development, a set of spacecraft flight-equivalent radio frequency communications equipment is tested prior to flight to verify the required system performance in the expected mission radio frequency environment.

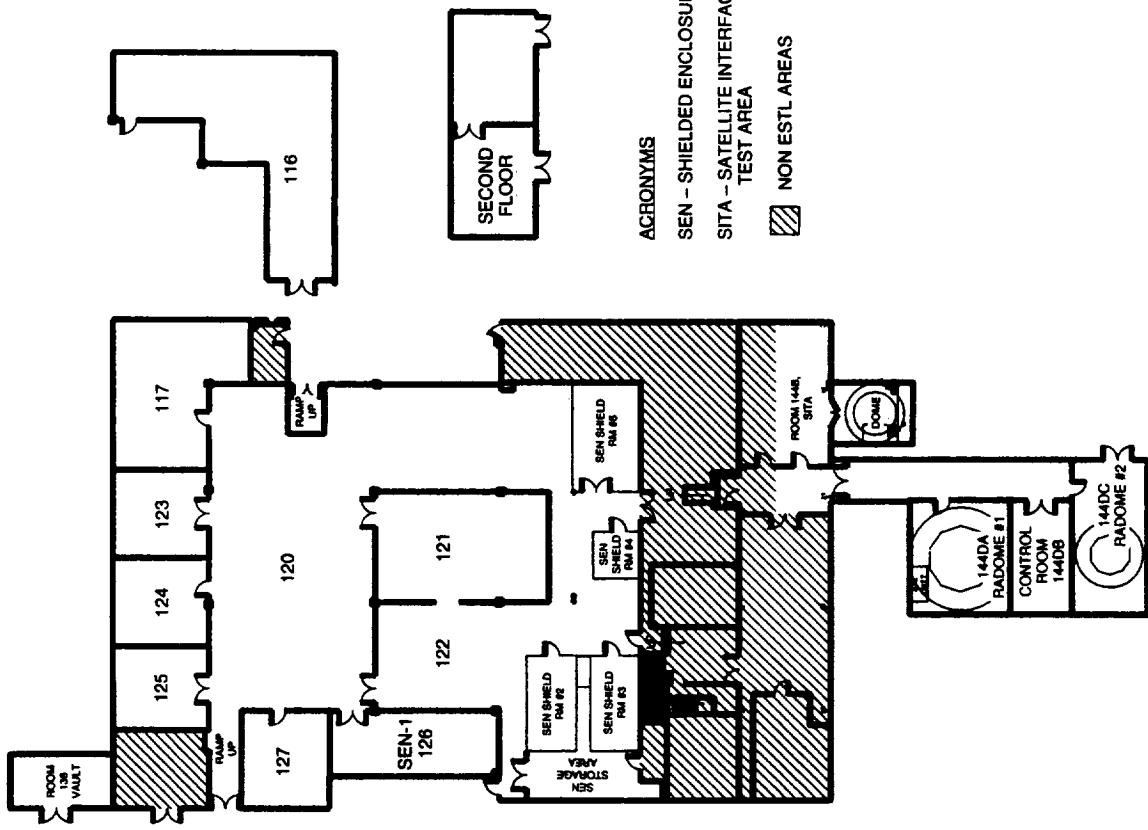
Throughout the design and development phases, laboratory personnel work closely with NASA contractor and vendor engineers to quickly resolve incompatibilities. In the operational phase of a program, the Electronic Systems Test Laboratory facility performs system level delta certification tests for radio frequency equipment modifications to the spacecraft, relay satellites, free-flyers, and ground stations. The laboratory is also utilized during the operations phase for investigation and resolution of communications anomalies experienced during a mission. Figure 5 depicts the Electronic Systems Test Laboratory Test Control Center providing real-time mission support during Space Transportation System (STS)-48. The flexibility and accessibility of equipment in a controlled environment provides a cost-effective facility to troubleshoot problems, determine a resolution, and develop corrective action.

DATA ACQUISITION: Methods consist of manual and computer-assisted data acquisition and recording from instrumentation, bit error detectors, spectrum analyzers, strip charts, etc.

**TABLE 1 - MAJOR ORBITER, GROUND STATION, AND SPECIAL SUPPORT EQUIPMENT  
IN THE ELECTRONIC SYSTEMS TEST LABORATORY**

Orbiter Equipment Complement			
UHF	Operational	S-band payload	Ku-band
EVA/ATC UHF transceiver	1. Antenna switch 2. Power amplifier 3. Preamplifier 4. Transponder 5. FM transmitter 6. FM signal processor	1. Payload interrogator 2. Payload signal processor	1. Deployed assembly 2. Electronic assembly 1 3. Electronic assembly 2 4. Signal processor assembly
Ground Station Equipment			
UHF	S-band	TDRS ground station (Shuttle unique)	Uplink data
UHF transceiver	1. Exciter 2. Receivers (3) 3. Ranging system		1. Shuttle command/voice multiplexer 2. Spacecraft command encoder 3. Delta modulation/demodulation 4. KGT-29 encryptor
Special Support Equipment			
1. Ranging/doppler simulator 2. Space loss simulators 3. Payload system simulator	4. TDRS satellite simulator 5. S-band RFI simulator 6. Payload interface control system	7. VAX 11/785 computer 8. 4.9 meter S-band antenna 9. Data recorders (4)	

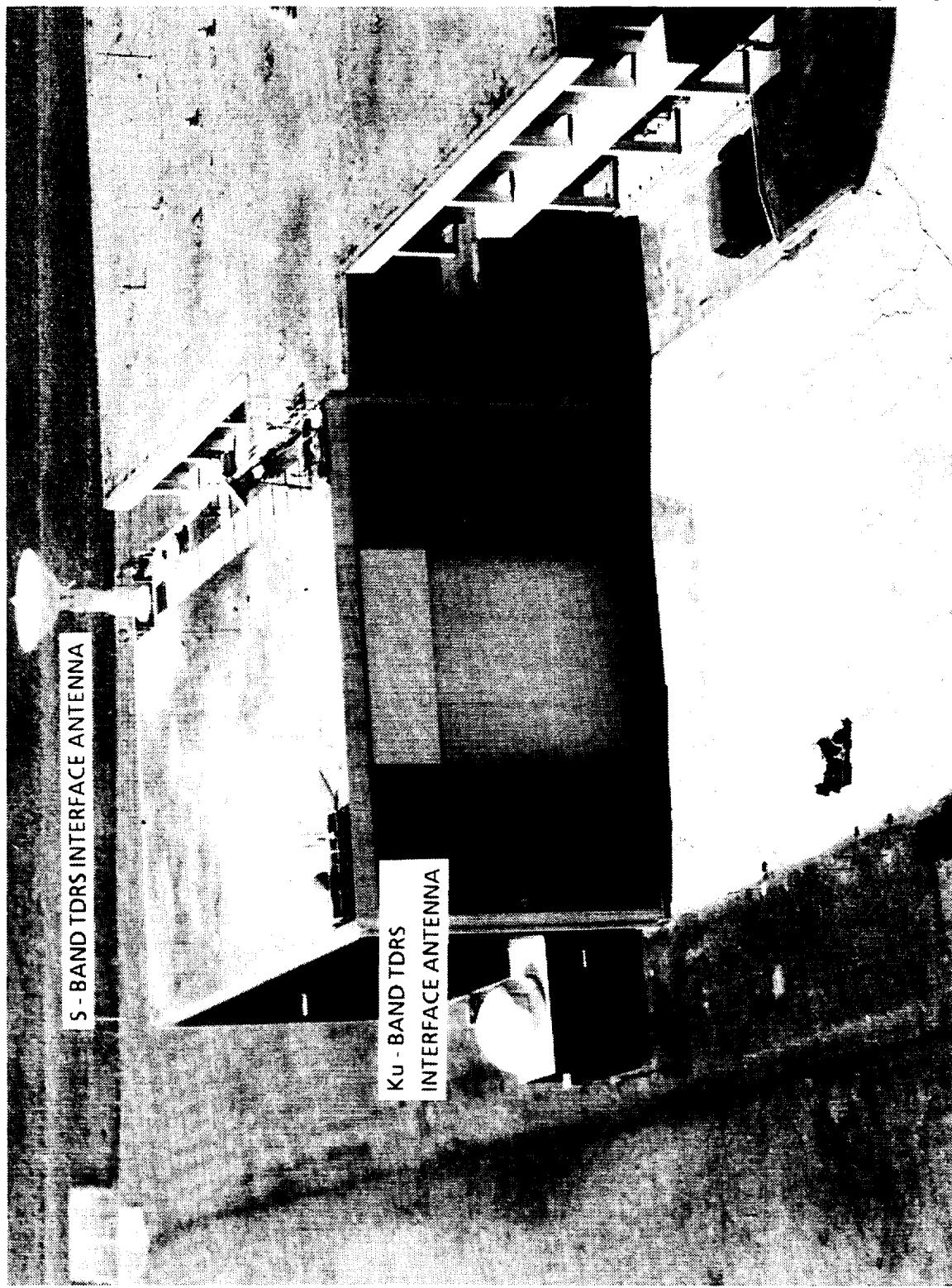
**FIGURE 1 - ELECTRONIC SYSTEMS TEST LABORATORY FLOOR PLAN**



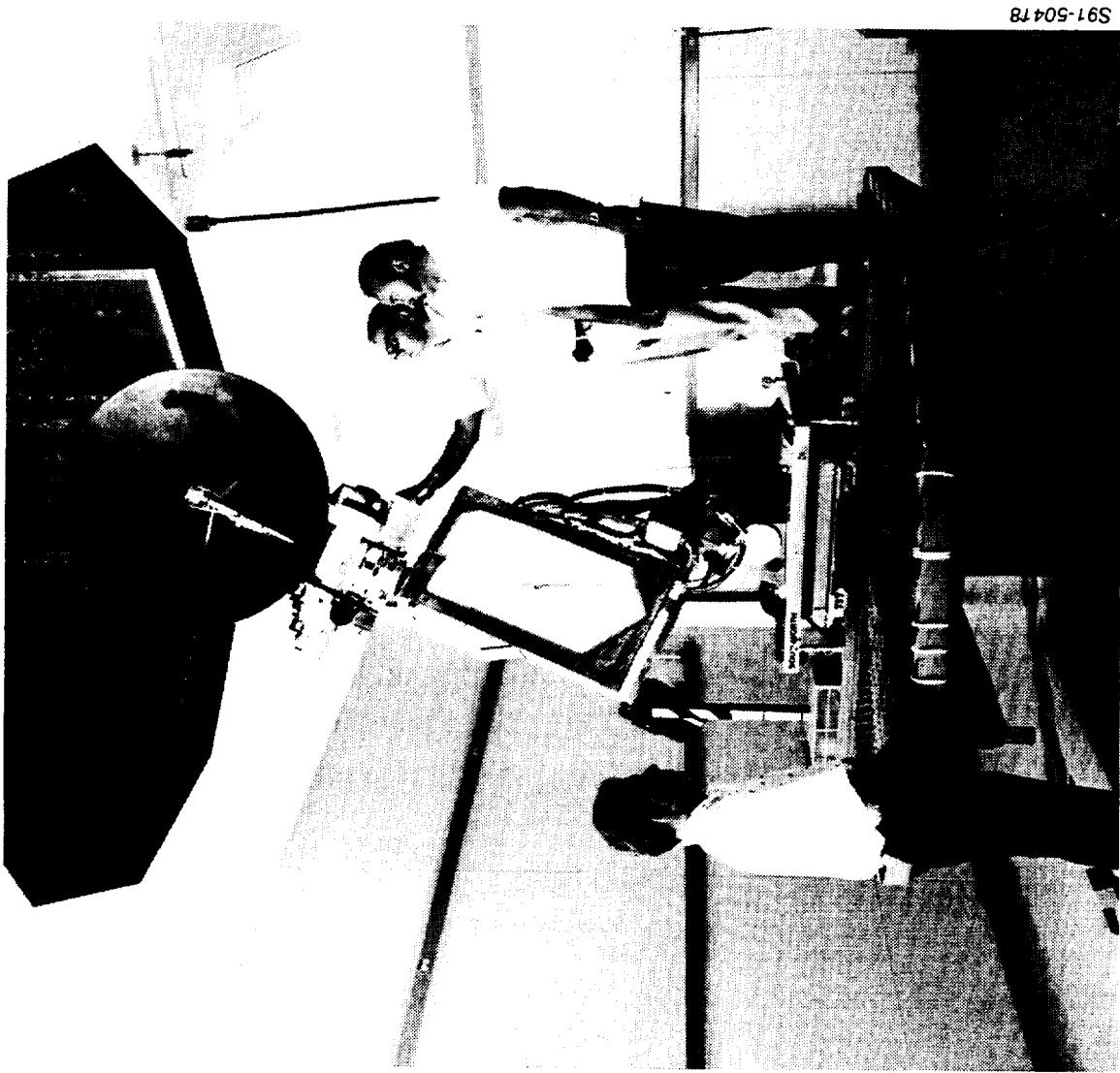
**ACRONYMS**

SEN - SHIELDED ENCLOSURE  
SITA - SATELLITE INTERFACE  
TEST AREA  
NON ESTL AREAS

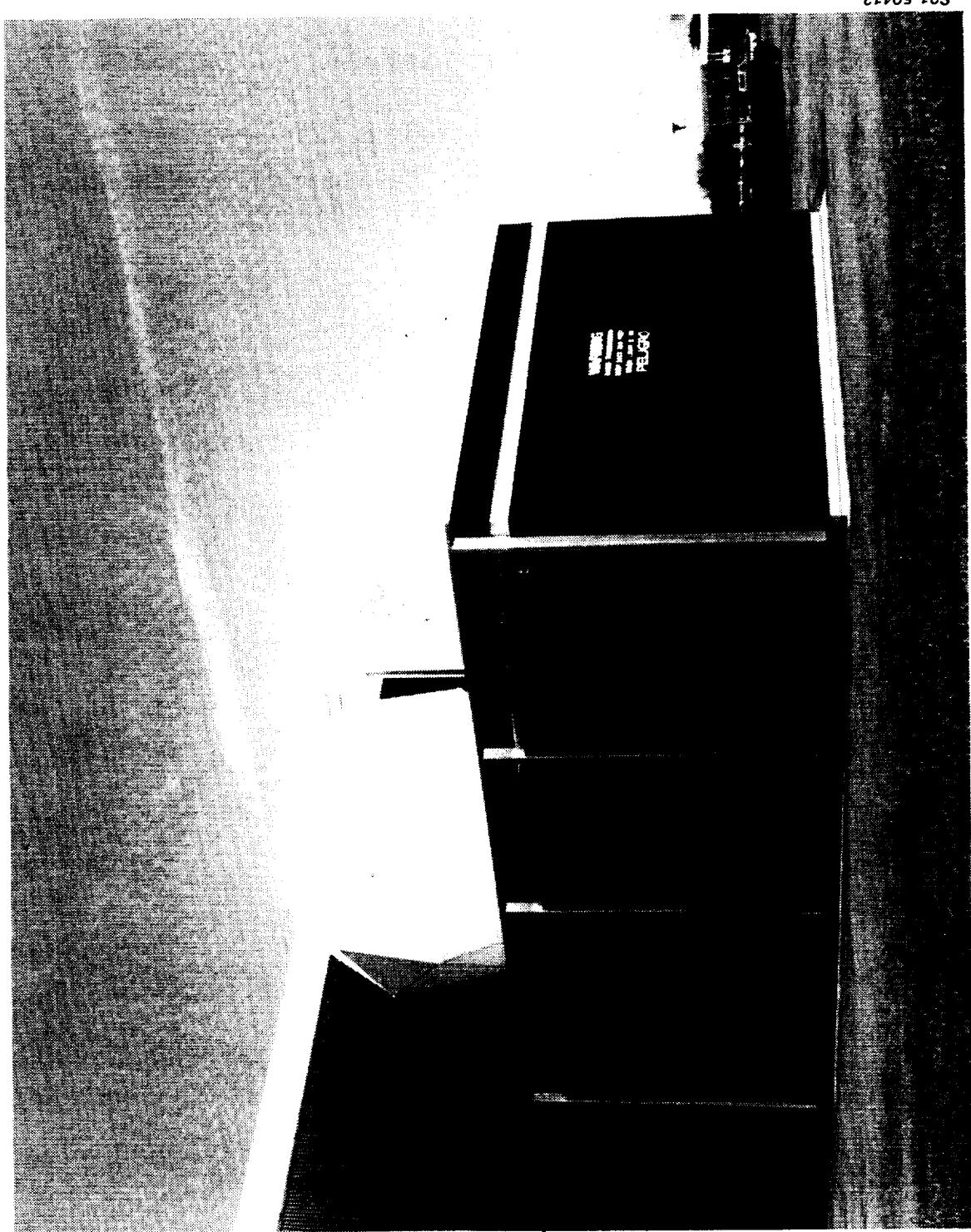
**FIGURE 2 - ELECTRONIC SYSTEMS TEST LABORATORY 4.9 METER S-BAND ROOFTOP ANTENNA**



**FIGURE 3 - ELECTRONIC SYSTEMS TEST LABORATORY ORBITER KU-BAND ANTENNA**



**FIGURE 4 - ELECTRONIC SYSTEMS TEST LABORATORY RADOME FACILITY**



**FIGURE 5 - ELECTRONIC SYSTEMS TEST LABORATORY TEST CONTROL CENTER**



## General Facility Specifications

### FLIGHT EQUIPMENT ASSEMBLY AREA

LOCATION: Building 44, Room 246

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1978

INITIAL COST: \$4k

REPLACEMENT COST: \$35k

USE: The Flight Equipment Assembly Area is used to develop, fabricate, modify, and repair flight and nonflight headsets and other audio hardware. The Assembly Area also cleans and bags that hardware for shipment. Once developed, maintenance of the hardware is typically transferred to the flight equipment processing contractor.

DESCRIPTION: This controlled-access facility has capability for fabricating and modifying flight and nonflight headsets and other audio Government-furnished equipment. It contains piece parts storage facilities, temporary controlled hardware storage facilities, three Class 100 clean benches, and anti-static discharge protection hardware. Flight cleaning and bagging can be performed if necessary. Limited in-process testing can be performed in the facility, but full acceptance testing is performed in other laboratories of the audio section.

Data processing equipment available includes a VAX 11/780 computer terminal for inventory and parts control.

DATA ACQUISITION: Terminal-to-VAX 11/780 connections enable inventory and parts control.

## **General Facility Specifications**

### **GLOBAL POSITIONING SYSTEM (GPS) LABORATORY**

**LOCATION:** Building 18, Second Floor

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1985 (began as capability added to Boresight Facility)

**INITIAL COST:** \$1,400k

**REPLACEMENT COST:** \$1,750k

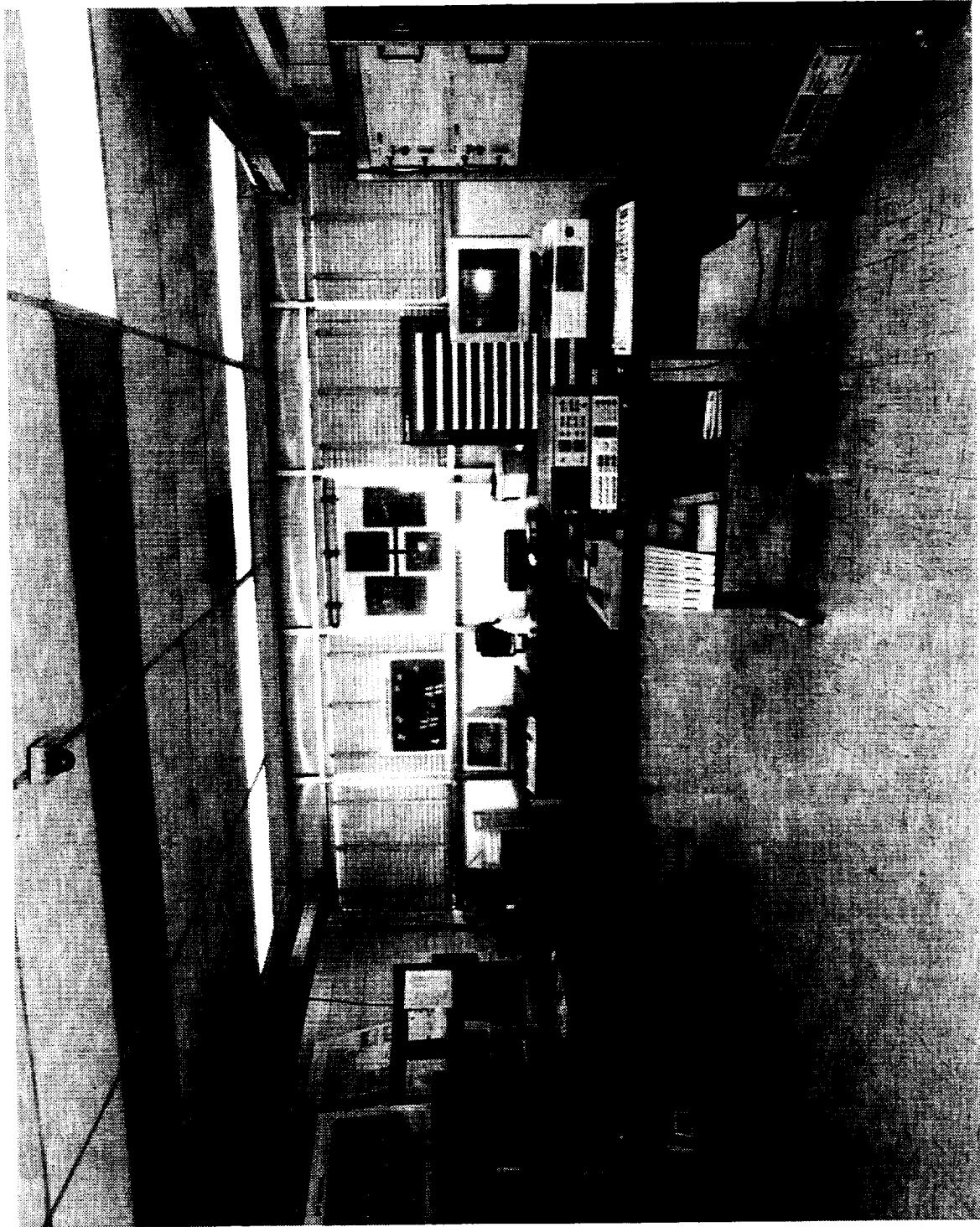
**USE:** The GPS Laboratory functions as a design, development, test, and evaluation and as a static and dynamic test facility for the GPS tracking and navigation components, subsystems, and systems for space GPS applications.

**DESCRIPTION:** The GPS facility consists of 37.2 square meters of laboratory space in the Radar Boresight Facility and utilizes the adjacent boresight and antenna ranges. The facility tracking testbed consists of the hardware and software tools required to evaluate the system's performance in the

absolute, relative, and differential modes. The tests are performed in the field on either the antenna range or over survey markers located at JSC and in the laboratory using the GPS Satellite Signal Simulator. The performance of the GPS is evaluated in land, air, and space vehicle dynamic scenarios. The test facility consists of the following hardware: two eight-channel coarse and acquisition code GPS receivers (used for field and laboratory testing); two four-channel, multiplex coarse and acquisition code and precision code GPS receivers (used for field and laboratory testing); one ten-channel coarse and acquisition code GPS receiver (used for satellite integrity monitoring); a reconfigurable ten-channel GPS satellite signal simulator with associated trajectory generators, receiver interface software, simulator drivers, and mission analysis software tools; two microwave ranging systems that provide a reference for determining GPS accuracies; and numerous software tools for evaluating GPS performance (GPS data analysis tools) and for scheduling GPS tests (e.g., satellite visibility and optimum satellite geometry determination).

**DATA ACQUISITION:** Data are acquired through manual and computer-assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

**GPS LABORATORY**



S91-52292

## **GOVERNMENT-FURNISHED EQUIPMENT FLIGHT HARDWARE DEVELOPMENT AND PROCESSING FACILITY**

### **General Facility Specifications**

LOCATION: Building 14, Room 301B

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1981

INITIAL COST: \$500k (not including construction of facility)

REPLACEMENT COST: \$1,100k (not including construction of facility)

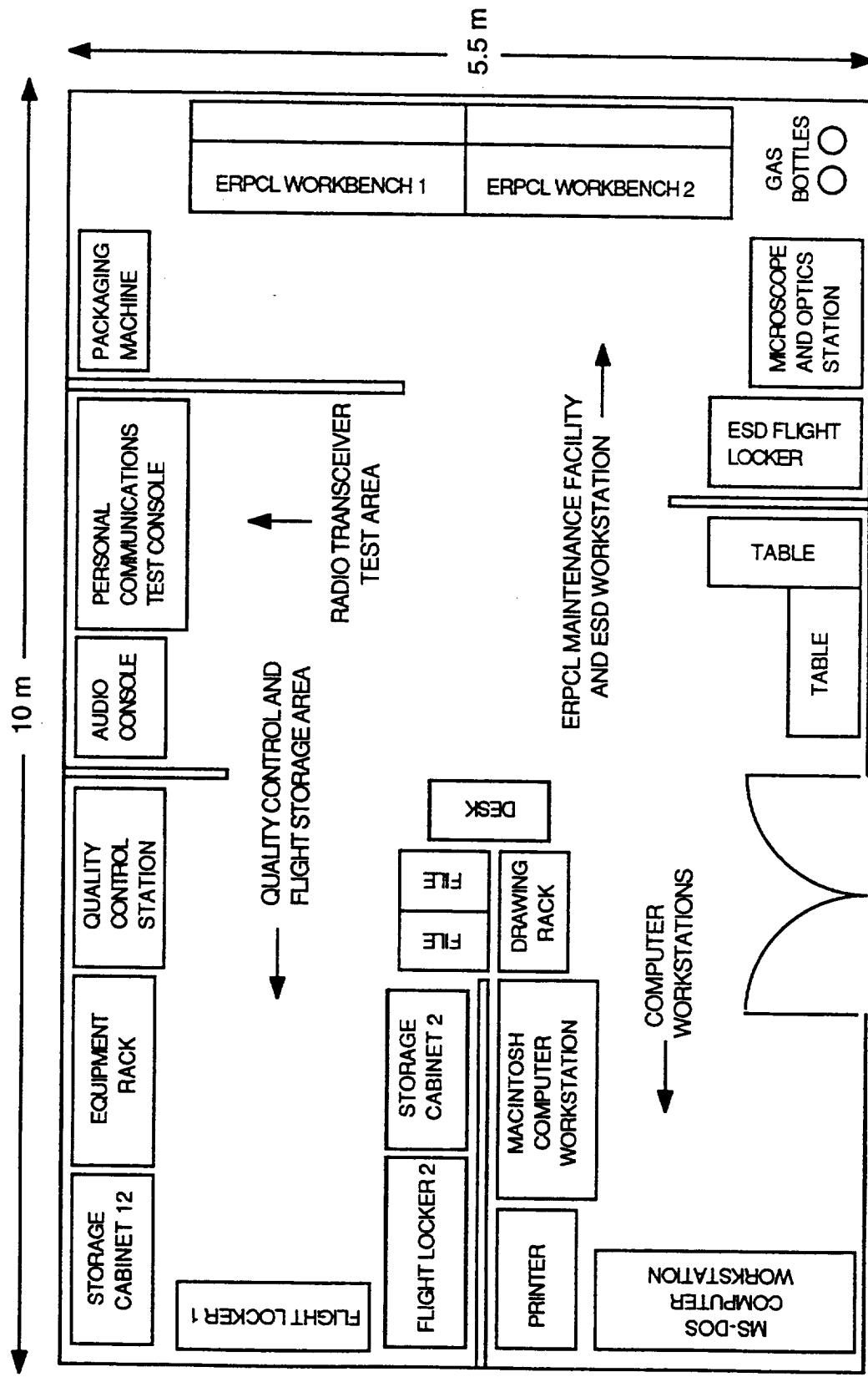
USE: The Government-Furnished Equipment Flight Hardware Development and Processing Facility has capability to provide radio frequency communication transceiver field support, as well as testing, evaluation, repair and development of Government-furnished equipment.

DESCRIPTION: This facility occupies approximately 50.17 square meters of space on the third floor of JSC Building 14. Designated as Room 301B, this laboratory currently contains the Extended Range Payload Communications Link test and

maintenance facility, a radio transceiver test area, and a quality control and flight storage area. The laboratory also contains an electrostatic discharge controlled workstation and two computer workstations. Located in the room are two workbenches, two configuration controlled test racks, three quality controlled flight lockers, an audio console, a packaging machine, and a microscope and optics station. Also located in the laboratory are tables, equipment racks, and file cabinets. Facility activities include the assembly and testing of the Extended Range Payload Communications Link, acceptance testing and flight maintenance of the PRC-112 Survival Radios, and subsystem support for the Ultra High Frequency Communications System and the Shuttle Amateur Radio Experiment, or SAREX. The computer workstation consists of a Macintosh II computer, a MS-DOS 386x personal computer, and a printer. Other laboratory equipment includes radio frequency generators, spectrum analyzers, modulation meters, power supplies, oscilloscopes, distortion analyzers, and other designated ground support equipment.

DATA ACQUISITION: Manual acquisition is made from test instrumentation, Macintosh II and DOS 386 computers, and an NTX printer.

## GOVERNMENT-FURNISHED EQUIPMENT FLIGHT HARDWARE DEVELOPMENT AND PROCESSING FACILITY FLOOR PLAN



## **General Facility Specifications**

### **HIGH-TEMPERATURE SUPERCONDUCTIVITY LABORATORY**

**LOCATION:** New facility being constructed during 1992

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1992

**INITIAL COST:** \$100k (excluding construction of facility)

**REPLACEMENT COST:** \$100k (excluding construction of facility)

**USE:** The High-Temperature Superconductivity Laboratory conducts testing of superconducting antennae and front-end radio frequency electronics; supports the development of antenna flight experiments.

**DESCRIPTION:** The recent discovery of high-temperature superconductor materials has spurred the development of tracking and communications systems which utilize these materials to enhance system performance. A research and design program, initiated with the support of the Director's Discretionary Fund, has been established to evaluate useful high-temperature superconductor materials and device designs.

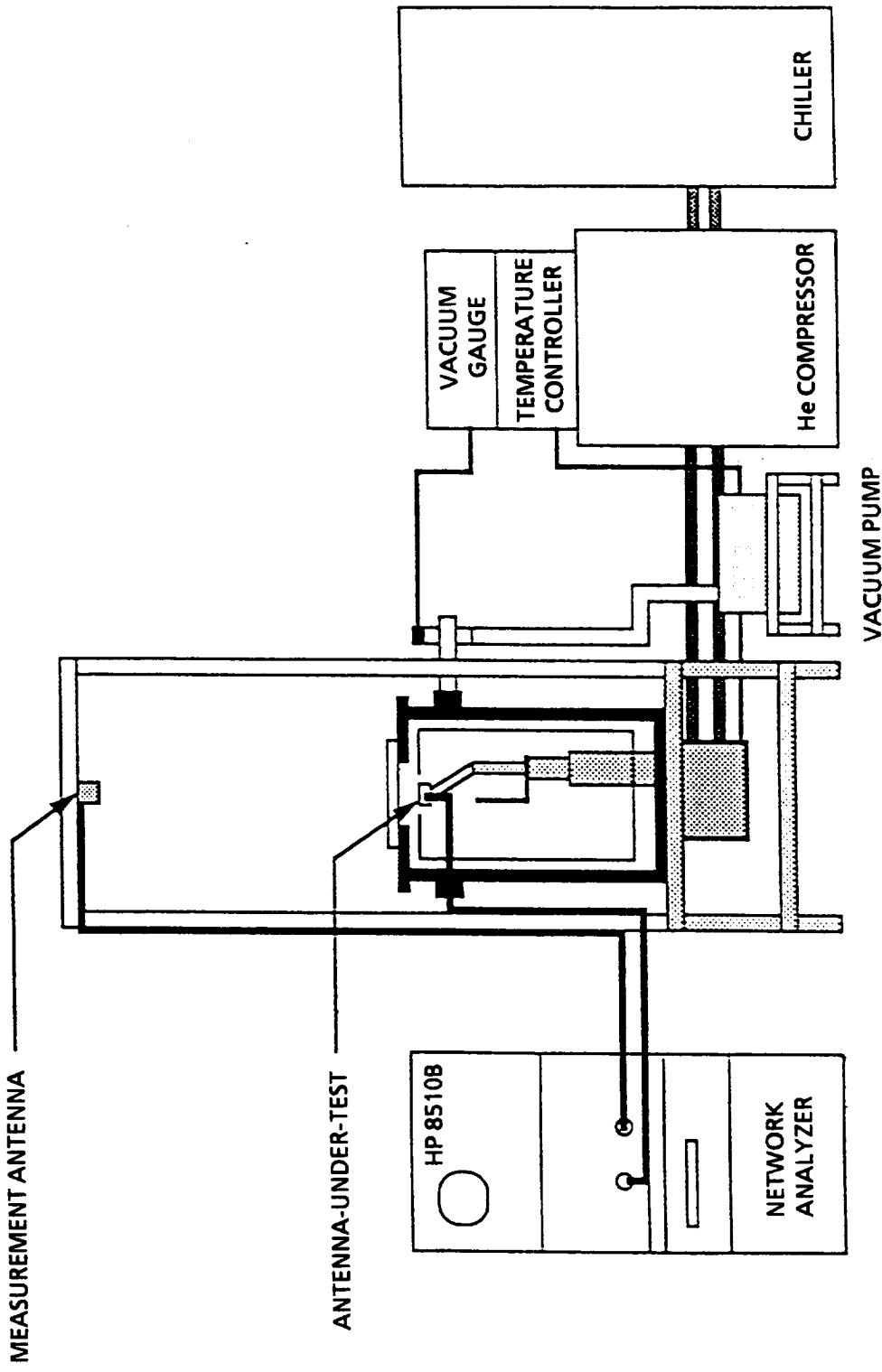
Antenna arrays are one type of structure that can benefit from the use of high-temperature superconductors. Efforts to design, fabricate, and test a sixteen-element subarray of aperture-coupled patch radiators with a corporate feed network implemented in high-temperature superconductor stripline are currently in progress. This work supports a proposed JSC/Lewis Research Center flight experiment employing a 144-element array and high-temperature superconductor/cryo-cooled, front-end equipment operating at K-band.

Laboratory facilities include two cryogenic chambers and associated equipment. The chambers have been modified to permit the testing of antennae as well as other electronic devices. One chamber is a three-stage design and cools to 4.5 degrees Kelvin. The other is a two-stage design cooling to twenty degrees Kelvin; its smaller size will permit more convenient measurement of antenna radiation patterns.

Laboratory personnel also support the monitoring of research contracts that have been awarded by NASA to other laboratories.

**DATA ACQUISITION:** Data are acquired through the use of the J14 antenna measurement facilities and network analyzers.

## LABORATORY EQUIPMENT CONFIGURED FOR RELATIVE ANTENNA GAIN/EFFICIENCY MEASUREMENT



## **General Facility Specifications**

### **HYBRID VISION LABORATORY**

**LOCATION:** Building 1, Room 133C

**POINT OF CONTACT:** Chief, Tracking and Communications  
Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1986

**INITIAL COST:** \$1,000k

**REPLACEMENT COST:** \$2,000k

**USE:** The Hybrid Vision Laboratory functions as a design, development, test, and evaluation laboratory for optical tracking and optical communications systems and subsystems. The facility is capable of supporting prototype-to-flight design, development, test, and evaluation.

**DESCRIPTION:** The 62.7-square-meter hybrid vision design, development, test, and evaluation area is for development of robotic, synthetic, and machine vision systems. Areas under development include optical correlator, video and infrared image processing for target recognition and tracking, and 3-D laser sensor and processing development. This area includes a fiber-optic network interface connecting it to other areas of JSC robotic development and test. It also includes a wide variety of standard optical and electronic development and test instrumentation, as well as such devices as lasers, detectors,

lenses, optical tables, and fiber-optic assembly and testing equipment. Complete development, analysis, and verification testing of active and passive components, subcomponents, and systems can be conducted in this facility.

Optical processing offers the possibility of faster, lighter weight, simpler vision systems for those applications that do not require the great power and generality of vision by digital image processing. The in-house investigation is advancing on several fronts--the development of advanced spatial light modulators; the development of special filtering algorithms for use in phase-only optical correlators, including impulse deconvolution and correlation pattern shaping; and the remapping of geometric images.

The optical processing of video data using spatial light modulators in a real-time optical correlator is being developed for use in robotic vision and proximity operations, such as docking, autonomous landing, and station-keeping. The system should be capable of identifying a specific object (or feature) and then determining the azimuth, elevation, range, roll, pitch, and yaw of the object. The hybrid system will make use of the high speed of optical correlation by transferring optical filters to the spatial light modulators at a rate of 120 filters per second from a digital computer, which will evaluate the correlator output from the charge coupled device imager and choose the next filter.

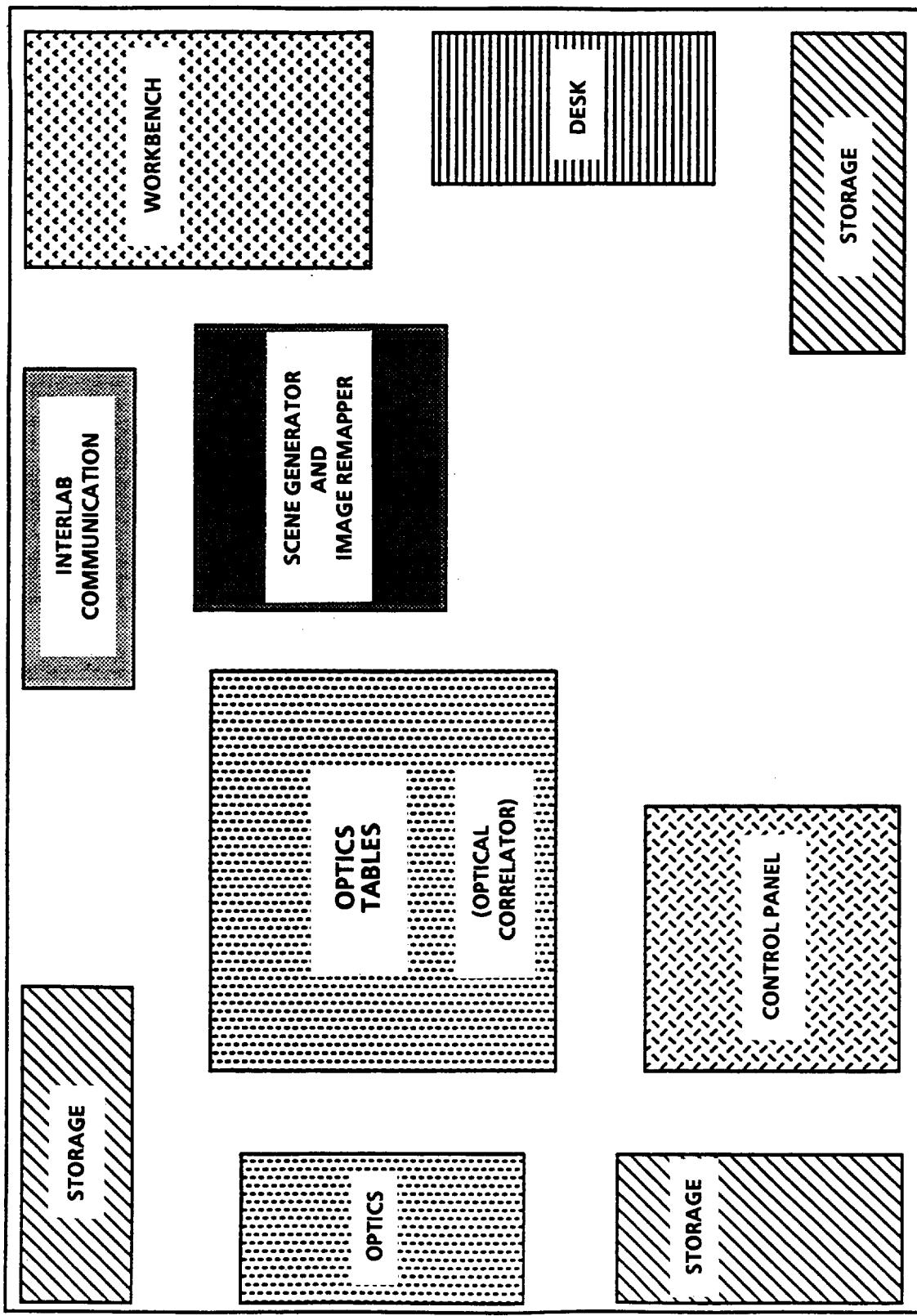
In order to realize the benefits of such a system, sets of filters and logical procedures for accomplishing specific tasks are being developed. Current work includes the evaluation of filters designed for the estimation of an object's attitude on various hardware configurations.

Special purpose image processing machinery provides the capability to combine direct geometric transformations on video

imagery in real time with subsequent information extraction by Fourier optics. Geometric Image Transformations for human low vision applications is also investigated in this facility.

DATA ACQUISITION: Data are acquired through manual and computer-assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

## HYBRID VISION LABORATORY



## General Facility Specifications

### IMAGE-BASED TRACKING LABORATORY

LOCATION: Building 14, Room 140

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1990 Conversion from Laser Tunnel Area

INITIAL COST: \$350k

REPLACEMENT COST: \$575k

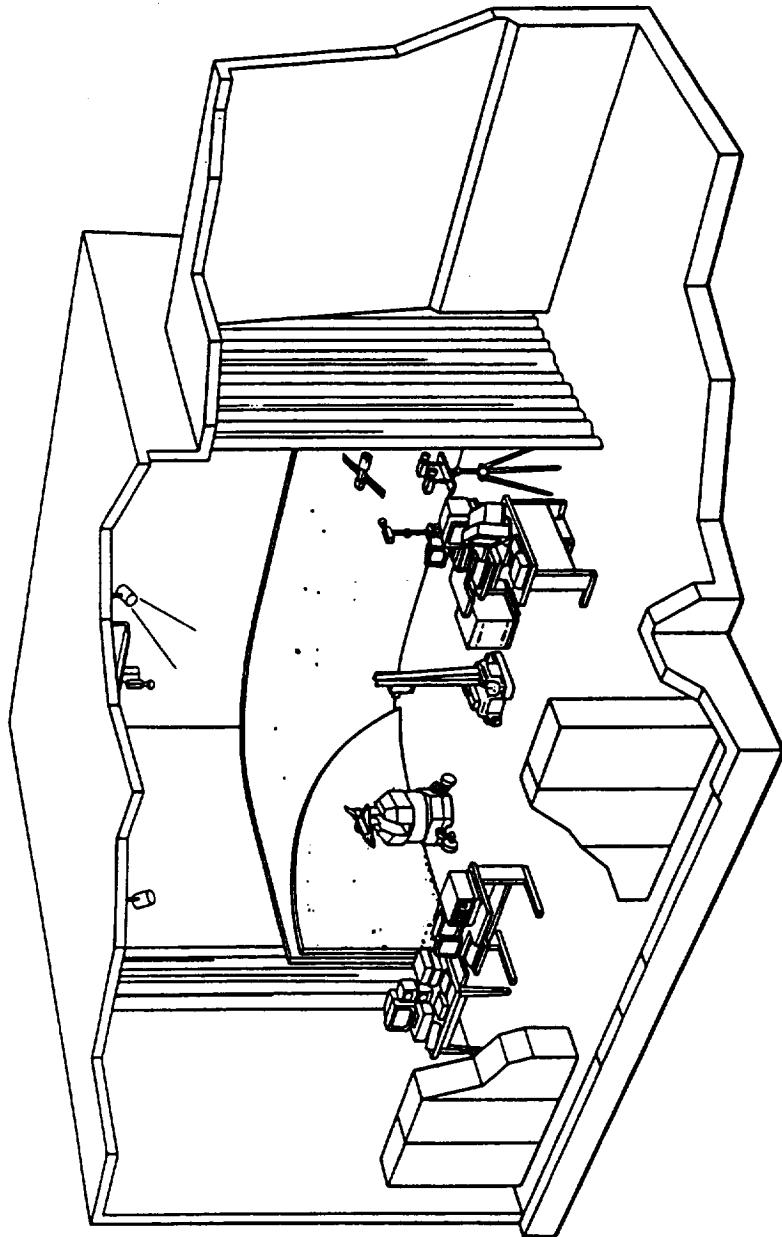
USE: The Image-Based Tracking Laboratory functions as a design, development, test, and evaluation and static and dynamic test facility for image-based tracking systems as well as components and subsystems.

DESCRIPTION: The 46.5-square-meter, image-based testbed is a development and evaluation facility for tracking systems which use imaging sensors as their primary input device. These sensors can range from simple video cameras to complex 3-D imaging laser rangers. The facility is specially designed to simulate the harsh lighting conditions encountered in space. To this end the floor and walls have been painted black and black curtains installed to separate the laboratory from the adjacent

six-degrees-of-freedom measurement facility and to absorb stray light. Bright lights mounted in the ceiling are individually controllable to simulate various lighting conditions. The facility is also equipped with mobile robots and target positioners which can be used to simulate the motions of two free bodies in space. The facility is further enhanced by the use of various backdrops which can simulate complex backgrounds. These backgrounds include Earth and star backgrounds as well as a mockup of the Martian surface. In addition, two-dimensional measurements of the mobile robots on the testbed floor can be obtained using a Precision Reference System. The Precision Reference System utilizes calibrated video cameras mounted along the ceiling to track the mobile robots on the floor. Taken together with the wide variety of image processing equipment available, the Image-Based Tracking Development Laboratory provides developers with an environment for solving the problems encountered in spaceborne, image-based tracking systems. The facility supports programs such as autonomous rendezvous and docking, autonomous landing, satellite servicing, EVA, retriever, and other tracking applications.

DATA ACQUISITION: Data are acquired through manual and computer-assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

**IMAGE-BASED TRACKING DEVELOPMENT FACILITY**



## General Facility Specifications

### MICROWAVE DESIGN LABORATORY

LOCATION: Building 14, Room 122A

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1986

INITIAL COST: \$200k (not including construction of facility)

REPLACEMENT COST: \$200k (not including construction of facility)

USE: The Microwave Design Laboratory has capability to provide computer-aided design and development of radio frequency and microwave (direct current to 32.5 gigahertz) integrated circuits including mechanical layout of the structures that house them.

DESCRIPTION: This facility comprises one room occupying approximately 18.6 square meters of floor space. The room contains computer-aided design workstations and the equipment required for running the software used in the design and development of radio frequency and microwave integrated circuits.

The current activity in this laboratory is the design and development of radio frequency and microwave components for

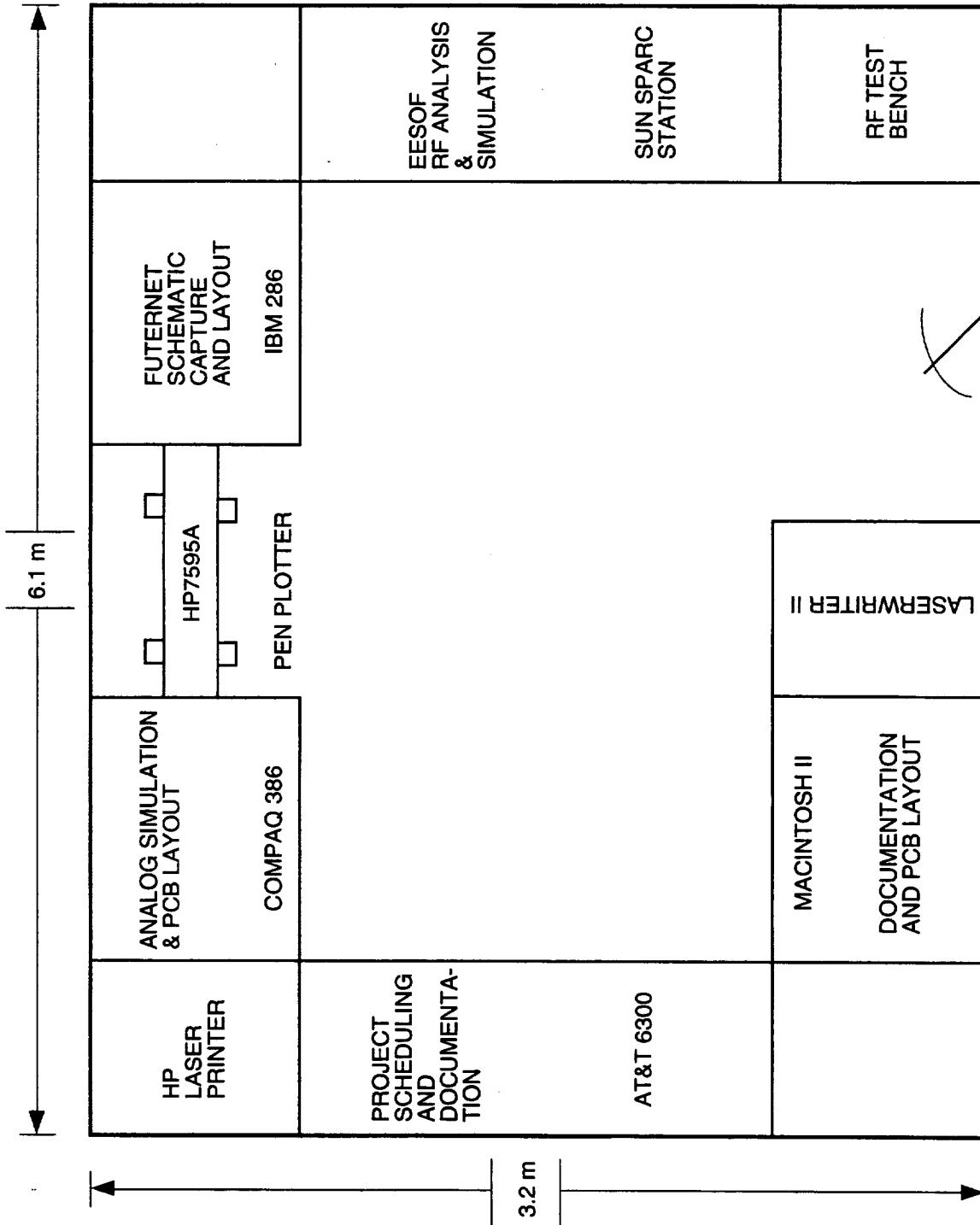
several ongoing projects including the following:  
communications for the Shuttle and Space Station Freedom, Advanced Communications Technology Systems Satellite, K- and Ka-band Component Development, Multiple Access Ultra-high Frequency Breadboard, and Assembly/Contingency Space Station Freedom Subsystem.

Major equipment items available in the facility are as follows:

- A SUN SPARC Station with a twenty-four-bit graphic display, CD-ROM and tape drive, two 450 megabytes harddrives, and thirty-two megabytes of random access memory
- A Compaq 386/20 megahertz computer with two megabytes of random access memory and a forty-megabyte harddrive
- A Macintosh II computer with eight megabytes of random access memory and a forty-megabyte harddrive
- An AT&T 6300 computer with a forty-megabyte harddrive
- Peripheral devices including a 7595A Hewlett Packard Plotter, a 7440 Hewlett Packard Plotter, a Hewlett Packard LaserJet Printer, two Epson dot matrix printers, and a Laserwriter II printer
- Design software including microwave design software by EEsot-Touchstn, E-SYN, Microwave Spice, Linecalc, Academy, and Omnisys; personal computer board layout software including ORCAD and PADS PCB with CADKEY mechanical software; mechanical software including an IGES translator for use with numerically controlled fabrication machines

DATA ACQUISITION: Manual acquisition is made from test instrumentation, spectrum analyzers, oscilloscopes, etc.

## MICROWAVE DESIGN LABORATORY FLOOR PLAN



## **General Facility Specifications**

### **MICROWAVE INTEGRATED CIRCUIT FACILITY**

**LOCATION:** Building 14, Room 132B

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1985; projected 1993 construction will double the facility's size.

**INITIAL COST:** Not available

**REPLACEMENT COST:** Not available

**USE:** Included within the Microwave Integrated Circuit Facility is an etching laboratory capable of etching gold laminated alumina and copper clad TEFILON (PTFE) substrates. Etching to line resolutions of 2.54 by 10<sup>-2</sup> millimeters (1 mil) with 2.54 by 10<sup>-2</sup> millimeters (1 mil) spacing is currently possible. The Microwave Integrated Circuit Facility maintains the capability to assemble and test microwave integrated circuits on substrate foundations etched in the etching facility.

**DESCRIPTION:** The Microwave Integrated Circuit Facility is housed inside a shielded, air-conditioned room of approximately 23.2 square meters; new construction slated for 1993 will double the size of the facility. The present shielded room is located inside the High Bay of Building 14. Workbenches, equipped for

ten work positions, are arranged along the interior walls of the room.

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1985; projected 1993 construction will double the facility's size.

**INITIAL COST:** Not available

**REPLACEMENT COST:** Not available

Equipment within the facility falls into two general categories: assembly equipment and test equipment. Assembly equipment available consists of split-tip welders, ball bond type wire bonder, wedge bond type wire bonder, die attach station, probe station, measurement microscope, stereo-zoom microscopes, ovens, hot plates, ultra-sonic parts cleaner, and enclosed, solvent recoverable hybrid parts cleaner. Test equipment consists of scalar analyzers capable of S-parameter measurements up to forty gigahertz, noise figure meter, oscilloscope, pulse generator, power supplies, plotters, and environmental temperature chamber.

Two assembly work stations are equipped with vertical flow laminar flow hoods, providing a class ten cleanroom environment for hybrid circuit and microwave integrated circuit fabrication.

Amplifiers, phase shifters, power dividers, frequency multipliers, synthesizers, and microstrip antennas depict the typical types of microwave integrated circuits and devices fabricated and tested in this facility. Use of strip line and microstrip technology in the design and construction of the circuits is common. Devices operating from twenty megahertz through thirty gigahertz have been developed in the facility.

**DATA ACQUISITION:** Manual acquisition is made from test instrumentation.

MICROWAVE INTEGRATED CIRCUIT FACILITY

ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH



## General Facility Specifications OPTICAL TRACKING AND COMMUNICATIONS LABORATORY

LOCATION: Building 14, Rooms 135 and 235

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1965; modified to present configuration 1985-87

INITIAL COST: \$520k

REPLACEMENT COST: \$2,489k (including building)

USE: The Optical Tracking and Communications Laboratory functions as a design, development, test, and evaluation laboratory for optical tracking and communications systems and subsystems. The facility is capable of supporting prototype-of-flight design, development, test, and evaluation.

tracking, communication, and communication systems can be conducted in this facility.

The design, development, test, and evaluation area is for the design, development, and evaluation of rendezvous, proximity operations, capture, and landing sensors and optical communications system components and flight hardware such as the laser docking sensor breadboards and flight experiment hardware. Different areas and equipment are provided for fiber-optic communication, short-range flood volume communication, and long-range point-to-point communication development activity.

This facility has been active since 1965, was modernized in 1981 and 1986 with new facilities to support program requirements, and will be upgraded to support Mars and lunar programs.

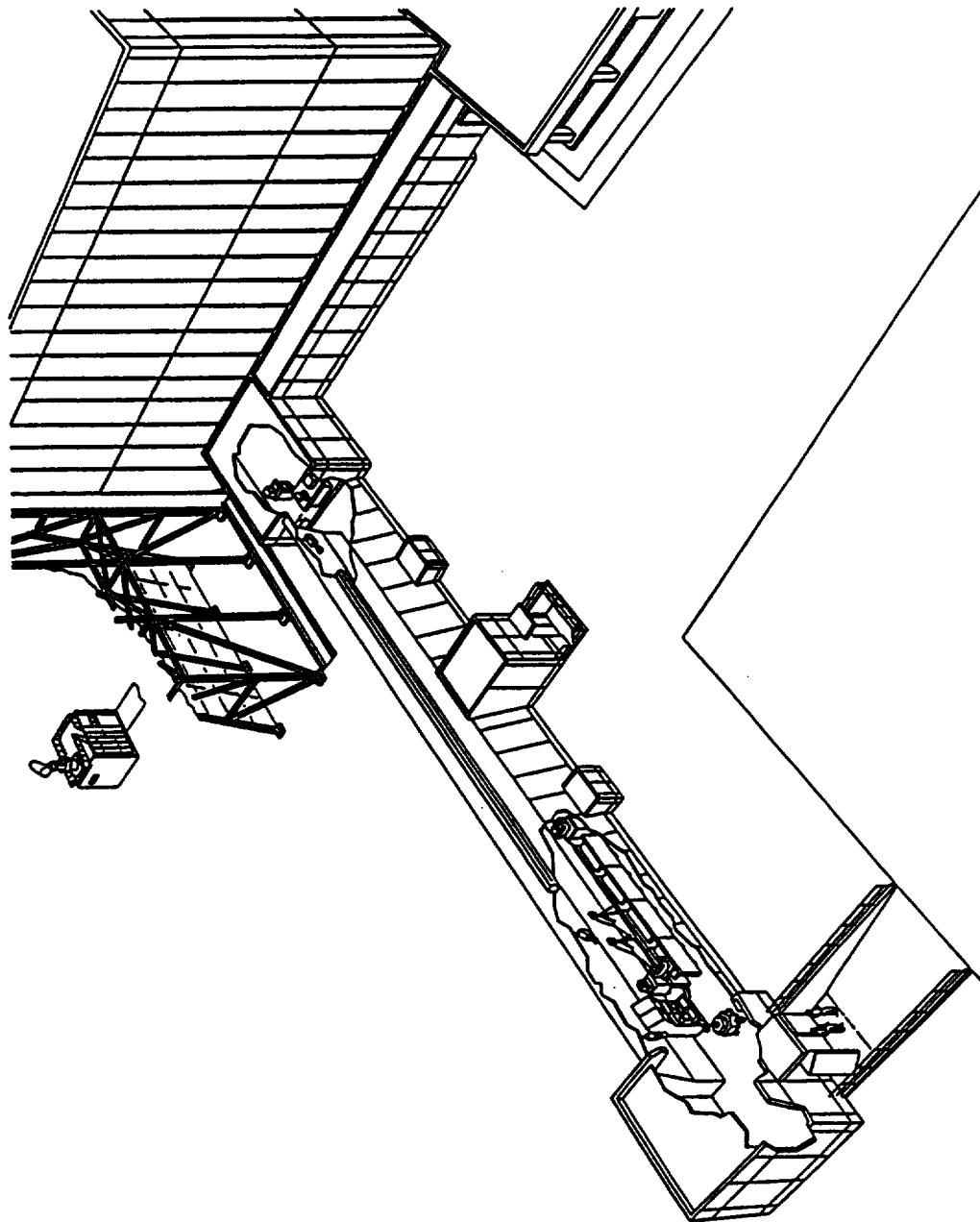
Utilized equipment includes the following:

- General optical and radio frequency electronic test equipment
  - Precision ranging equipment
  - Precision theodolites
  - Six-degrees-of-freedom target positioner
  - Computer-aided design and computer-aided engineering systems
  - Position reference systems
  - Audio analyzer
  - Impedance analyzer
- DESCRIPTION: This 465-square-meter facility consists of the development and test areas for several systems. Included are a wide variety of standard optical and electronic development and test instrumentation and devices such as gas, semiconductor, and solid-state lasers, detectors, lenses, optical tables, fiber-optic assembly and testing equipment; computer-aided design and engineering equipment; and specialized capabilities which are further detailed below. Complete development, analysis, and verification testing of active and passive video and infrared

- Digital signal processing tools
- Prom tools
- Broad stock of electronic, electrical, and electromechanical, as well as optical components

DATA ACQUISITION: Data are acquired through manual and computer-assisted data methods and through recording from systems of devices under test, instrumentation, and reference systems.

## OPTICAL TRACKING AND COMMUNICATIONS LABORATORY



## **General Facility Specifications**

### **OUTDOOR ANTENNA RANGE FACILITY**

LOCATION: Adjacent to Building 14, including mobile vans

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1965

INITIAL COST: \$584k

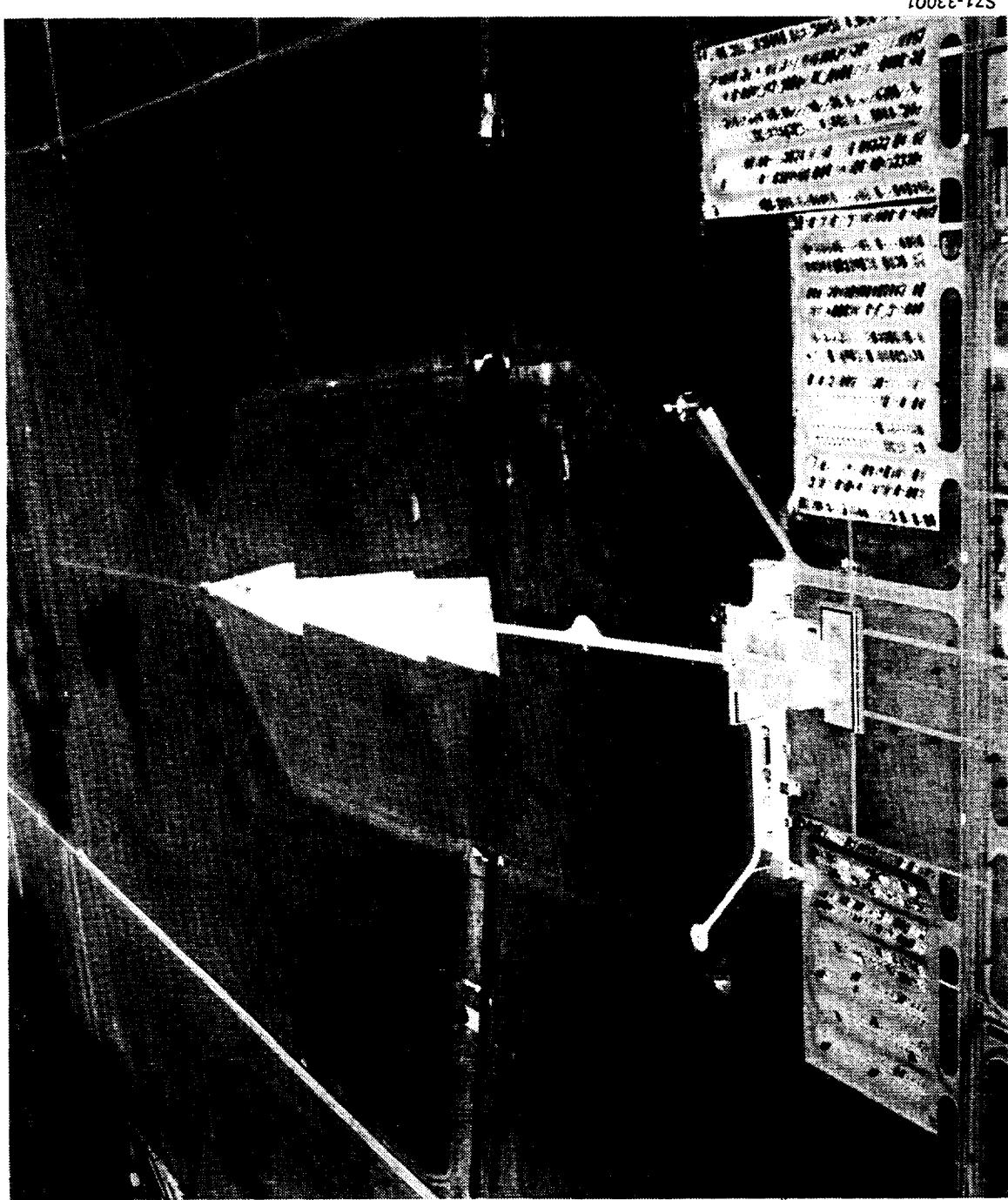
REPLACEMENT COST: \$750k

USE: The Outdoor Antenna Range Facility supports radiation pattern testing for the Space Shuttle Program and follow-on manned space programs. Wide frequency coverage (one to twenty-six gigahertz) is provided and multiaxis positioners can support 3336- to 4448-newton test items. A large 186 156-square-meter level field with tapered paving is available for large apertures and a smaller range with instrumented mobile vans is used to support existing programs.

DESCRIPTION: This antenna range facility is represented by a 91.4-meter-long, outdoor model range together with two instrumented mobile vans. One van is used as a transmitting source site, complete with crank-up transmitting antenna tower. The van is air-conditioned for environmental purposes. The second van, located at the receiving positioner site, is equipped with a full set of operating and recording consoles. This van location enables the operator to observe the operation of the test item on the model positioner while sitting at the console. This van is also air-conditioned for environmental control. The recording consoles provide rectangular or polar plots, radiation amplitude and phase plots, or all the selected data may be written on magnetic tape. The installed frequency coverage capability is one to twenty-six gigahertz. Another model range is located on a 186 156-square-meter plot behind Building 14. A 762-meter paved strip provides the capability of supporting a larger outdoor antenna range planned for future programs. A 24.4-meter-high, steel transmitter tower with two air-conditioned shelters is provided for future use.

DATA ACQUISITION: Manual acquisition is made from test instrumentation, spectrum analyzer, strip charts, etc.

**OUTDOOR ANTENNA RANGE**



## **General Facility Specifications**

### **PRECISION SIX-DEGREES-OF-FREEDOM TEST FACILITY**

LOCATION: Building 14, Room 135

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1989

INITIAL COST: \$1,050K

REPLACEMENT COST: \$1,750K

USE: The Precision Six-Degrees-of-Freedom Test Facility functions as a precision design, development, test, and evaluation static and dynamic test facility for laser radar and image-based tracking systems.

DESCRIPTION: The Test Facility is part of the tracking system testbed indoor test range for developing, calibrating, and testing various types of proximity operations and robotic tracking systems. The Six-Degrees-of-Freedom Facility features a six-degrees-of-freedom target positioner. The six-degrees-of-freedom positioner consists of sensor and target positioning gimbals and a twelve meter granite rail. The sensor gimbal uses two servo motor rotary states of plus or minus forty-five degrees at maximum rates of forty degrees per second and an

accuracy of 0.002 degrees. The sensor gimbal is attached to an airbearing table which rides on the granite rail and is stepper motor driven at a maximum rate of 0.5 meter per second with an accuracy of plus or minus five microns per meter. The target gimbal assembly consists of three servo motor rotary stages to provide yaw, pitch, and roll accuracies and rates equal to those of the sensor gimbal system except for roll, which has a maximum angular rate of ten degrees per second.

Six-Degrees-of-Freedom Subassemblies:

#### Calibrated Rail System

- Rail mounted on granite structure
- Stepper motor measures range change

#### Two-Axis Sensor Positioner

- Consists of two rotary stages to simulate azimuth and elevation parameters
- Mounted on stepper motor assembly

#### Three-Axis Target Positioner

- Consists of three rotary stages to simulate yaw, pitch, and roll parameters

Master Controller Computer

- Twenty-five megahertz 80 386 microprocessor
- Controls rotary and linear stages through Institute of Electrical and Electronic Engineers Standard 488 (IEEE-488) connected to sensor and target drive electronics
- Azimuth and elevation angles: plus or minus ninety degrees
  - Angle rates: six degrees per second (maximum)
  - Accuracy: 0.002 degrees
  - Resolution: 0.001 degrees
- Yaw and roll angle: plus or minus 180 degrees
  - Pitch angle: plus or minus ninety degrees
  - Angle rates: six degrees per second (maximum)
  - Accuracy: 0.002 degrees
  - Resolution: 0.001 degrees

Supporting Systems

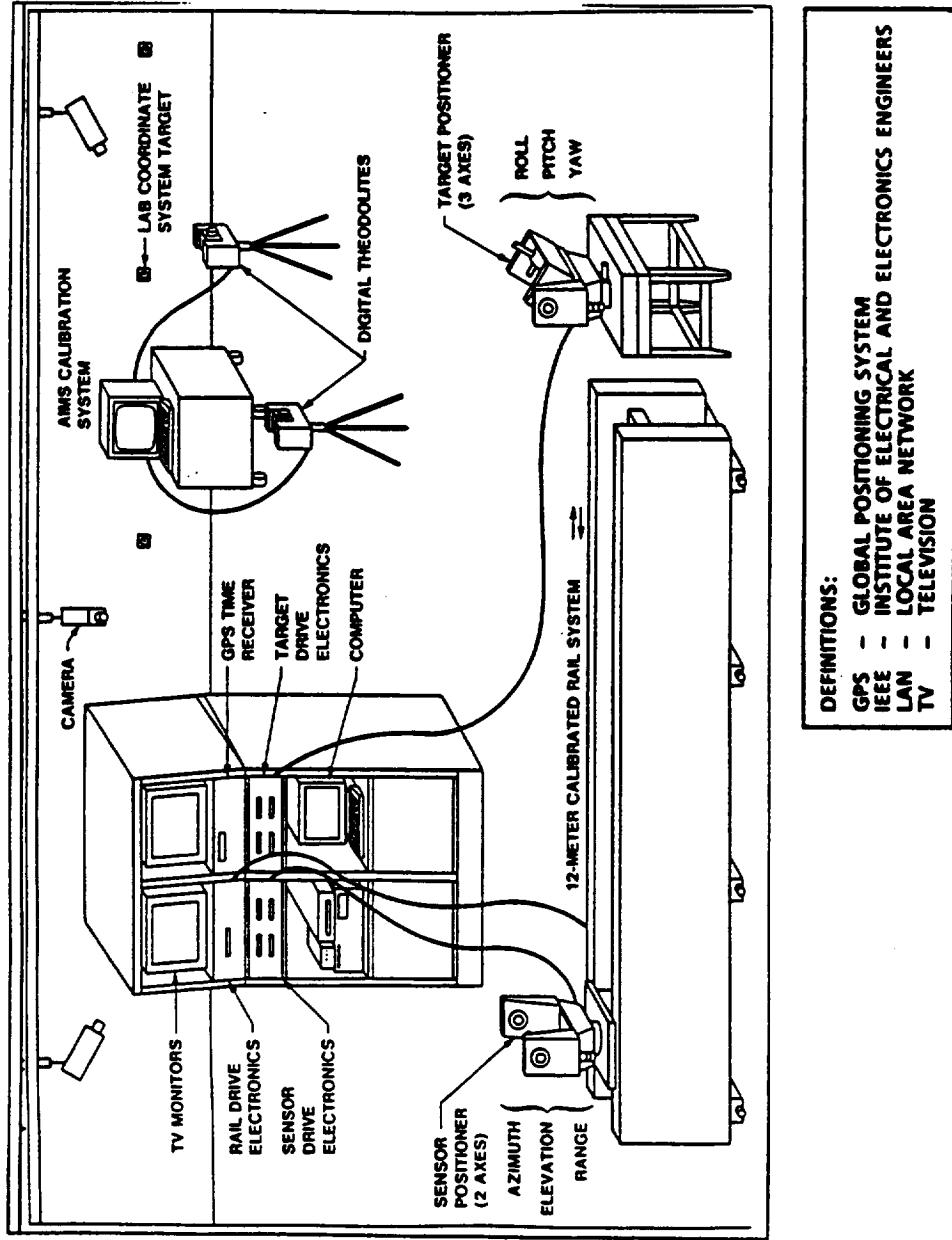
- Analytical Industrial Measuring System calibration system
- GPS time receiver
- Closed circuit television and monitor system
- Rate meter
- Interferometer

Six-Degrees-of-Freedom System Parameters and Accuracies

- Range: twelve meters (expandable)
  - Rate: 0.4 meter per second (maximum)
  - Accuracy: plus or minus ten microns per meter
  - Resolution: five microns per meter

DATA ACQUISITION: Data are acquired from manual and computer assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

## PRECISION SIX-DEGREES-OF-FREEDOM TEST FACILITY



## General Facility Specifications

### RADAR BORESIGHT FACILITY

LOCATION: Buildings 18 and 450 and Boresight Range

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1965

INITIAL COST: \$250k (Accumulative: \$775k, not including GPS Laboratory, collocated in Building 18, Second Floor)

REPLACEMENT COST: \$1,250k

USE: The Radar Boresight Facility functions as a design, development, test, and evaluation facility for elevation and performance verification of radar, radio frequency Nav aids tracking, and GPS.

DESCRIPTION: This facility provides for system static and dynamic testing and evaluation of radar, landing, and GPS systems. The facility's resources include an outdoor range with electromagnetic control fences, three-axis positioner, field strength probes, control center, measurement instrumentation, reference standards, and data reduction automatic data processing equipment for static testing and performance measurements. In addition, the facility has two position reference systems with computer control and data collection for dynamic testing and evaluation of radar and GPS systems.

This facility can be used with the Ku-band Radar System located in the Building 44 Electronic Systems Test Laboratory and along with the range transmitting tower located 762 meters away to measure and evaluate Ku-band radar performance, to verify Ku-band radar target tracking performance, and to make radar cross section measurements.

The 83.6-square-meter facility is housed in a two-story structure. The facility uses an antenna range transmitting tower located 762 meters away. The facility was built to test the Apollo rendezvous radar and the lander radar. The facility was upgraded to a boresight facility which supported the following Shuttle systems: Rendezvous Radar, Microwave Scanning Beam Landing System, and Tactical Air Navigation System.

The facility recording, receiving, and control equipment is located on the second floor of Building 18. The positioning equipment located on the roof consists of a heavy-duty, three-axis antenna positioner independently mounted directly from the ground on temperature stabilized columns.

The following are boresight range specifications and capabilities:

- Length: approximately 762 meters
- Reflectivity level: thirty-five decibels
- Angular read-out of the positioner: ten arcs per second
- Range validation: 4.6 by 4.6 meters quiet zone in front of the positioner

**DATA ACQUISITION:** Data are acquired through manual and computer-assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

## RADAR, NAVAIDS, AND GPS RANGE FACILITY



## **General Facility Specifications**

### **RADAR LABORATORY**

**LOCATION:** Buildings 14, Room 133B

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1983

**INITIAL COST:** \$85k (\$550k with accumulated equipment and systems)

**REPLACEMENT COST:** \$950k (not including the Pershing Reference Scene Correlation Guidance and Analysis System)

**USE:** The Radar Laboratory functions as a design, development, test, and evaluation facility for tracking subsystems and systems. The facility is capable of supporting prototype design, development, and flight article testing.

**DESCRIPTION:** The Radar Laboratory is a 46.5-square-meter radar and radio frequency navigation aids design, development, test, and evaluation facility. As such, the laboratory designs, develops, and evaluates on a continuing basis the components, subsystems, techniques, and systems applicable to multi-target radar, millimeter wave high-precision radar, other advanced

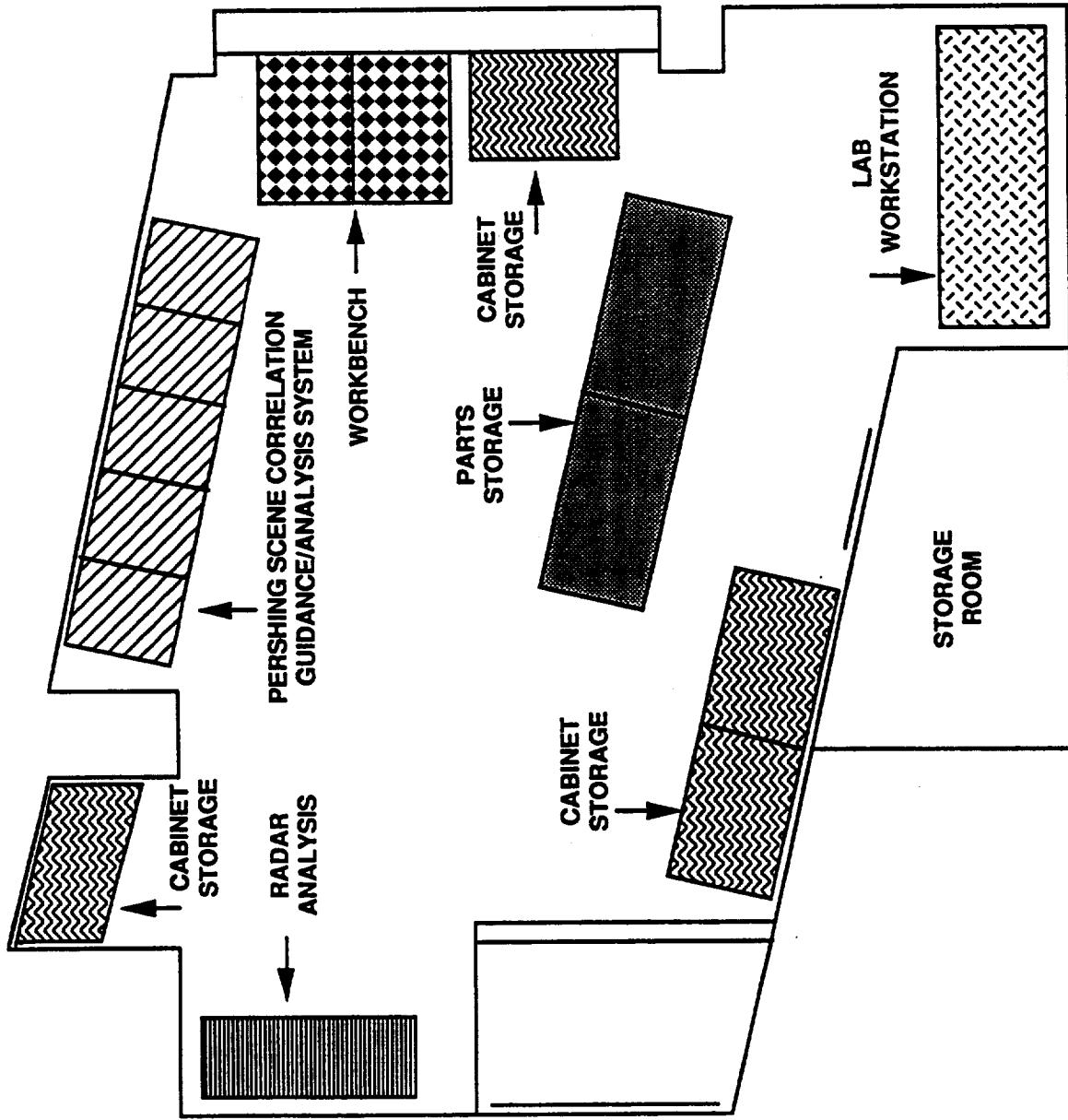
program and flight demonstration radar systems, landing systems, and GPS hardware for Shuttle, Space Station Freedom, and advanced programs for landing tracking and control, target tracking, rendezvous, and docking. The equipment inventory includes test instrumentation, transmitters, receivers, detectors, frequency generators, counter, digitizers, analyzers, synthesizers, and noise sources which span a spectrum from radio frequencies to millimeter wavelengths.

A computer-aided design and engineering workstation is included in the inventory. This workstation is equipped with software for radar performance analysis and radar cross section model development. The workstation includes a 486/33 personal computer, a laser printer, and a pattern plotter. The workstation also connects the VAX and Amdahl/Cray containing unique software radar performance analysis and radar cross section model development. Video equipment is included for viewing tapes from Shuttle mission operations.

Complete development, analysis, and verification testing of radar and landing systems can be conducted in this facility.

**DATA ACQUISITION:** Data are acquired through manual and computer-assisted data methods and through recording from systems or devices under test, instrumentation, and reference systems.

RADAR LABORATORY



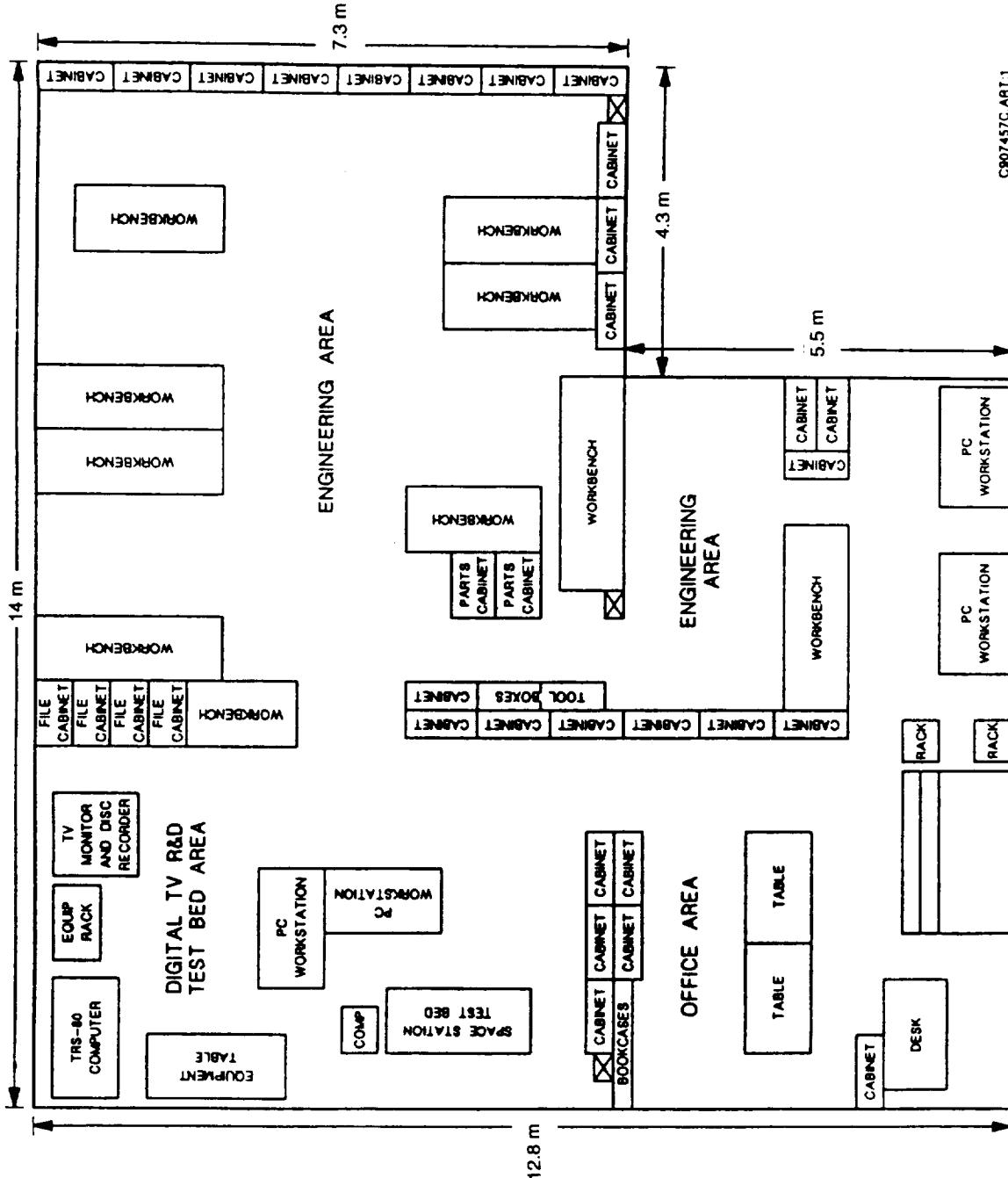
## **General Facility Specifications**

### **SIGNAL PROCESSING LABORATORY**

<b>LOCATION:</b> Building 44, Room 132	packetization techniques, and error correction coding equipment
<b>POINT OF CONTACT:</b> Chief, Tracking and Communications Division, Code EE, (713) 483-2873	These capabilities make it possible for the laboratory to support the following types of programs:
<b>STATUS:</b> Active	<ul style="list-style-type: none"><li>• Shuttle: Spacecraft signal processor test, calibration, mission support, and anomaly analysis; fundamental design and demonstration of improved signal processing techniques</li><li>• Space Station Freedom: Fundamental design, fabrication, test, and demonstration of error correction and decoders; audio linear predictive coders and decoders; digital data interleavers and demultiplexers; and digital data packetizers and formatters</li></ul>
<b>YEAR BUILT:</b> 1966	The laboratory capabilities have been enhanced by the addition of computing equipment and associated peripherals, including terminals, disc drives, cathode ray tube displays, and line printers to support design and development testing of various signal processing subsystems. Other items of laboratory equipment consist of standard laboratory oscilloscopes, data and logic analyzers, signal generators, data synchronizers, error analyzers, and television encoding and synchronization equipment. A significant level of current activity is the development of Space Station digital television and signal processing systems in which breadboards and prototype systems are under evaluation.
<b>INITIAL COST:</b> \$500k	<b>USE:</b> The Signal Processing Laboratory has capability for the development and testing of digital communication signal processing equipment, command system equipment, source and channel coding equipment, and digital television techniques.
<b>REPLACEMENT COST:</b> \$1,000k	<b>DESCRIPTION:</b> This facility is designed to accommodate work in the areas of space vehicle equipment engineering and digital signal processing development. The following capabilities are available in the facility: <ul style="list-style-type: none"><li>• Design, fabrication, test, and analysis of communication signal processors, command decoders and encoders, modulators and demodulators, multiplexers and demultiplexers, and bit synchronizers</li><li>• Development and evaluation of digital television techniques and bandwidth compression algorithms, digital data</li></ul>

**DATA ACQUISITION:** Manual acquisition is made from test instrumentation; spectrum analyzers, strip charts, digital oscilloscopes, logic analyzers, etc.

## SIGNAL PROCESSING LABORATORY FLOOR PLAN



Engineering Directorate Technical Facilities Catalog - JSC-19295

Tracking and Communications Division (EE) – January 1993

## SIGNAL PROCESSING LABORATORY



## **General Facility Specifications**

### **TELEVISION SYSTEMS LABORATORY**

**LOCATION:** Building 44, Room 134

**POINT OF CONTACT:** Chief, Tracking and Communications Division, Code EE, (713) 483-2873

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** \$50k (not including construction of facility)

**REPLACEMENT COST:** \$1,500k (not including construction of facility)

**USE:** The Television Systems Laboratory has capability for design, development, test, and verification of spacecraft television, ground facilities processing equipment, and television systems.

**DESCRIPTION:** The Television Systems Laboratory contains equipment and facilities for the development, testing, evaluation, and flight qualification of spacecraft television systems, including system components for ground processing. The laboratory also contains specialized equipment for the development, testing, and evaluation of sophisticated video processing systems (i.e., automatic focusing systems) to be integrated with spacecraft

television systems. More specifically, the laboratory has the following equipment and capabilities:

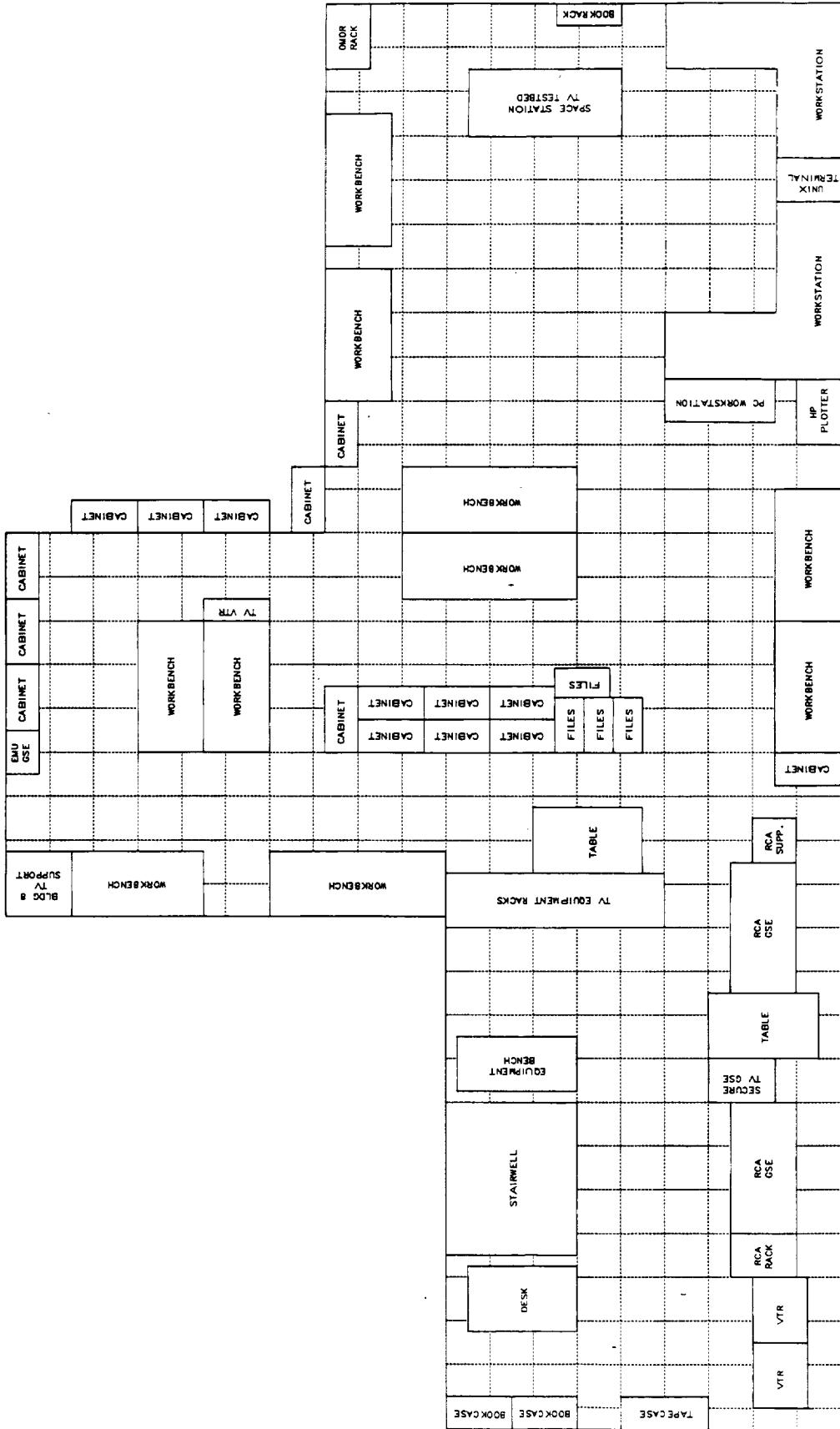
- Equipment for test and evaluation of the television cameras and monitors (and associated ground support equipment) which will be used for the Shuttle program
- Microcomputer development systems and computer-based schematic capture systems for use in design and development of video components and subsystems
- Specialized equipment for the development and evaluation of highly sophisticated time-division multiplexing equipment to interleave video and audio signals
- Capabilities for the development of both analog and digital video bandwidth compression techniques
- Specialized ground support equipment for the simulation and evaluation testing of complete spacecraft video systems, including anomaly investigations during flight missions
- Television: Ampex VPR-2B and JPR-300 record and reproduce systems compatible with National Television Standards Code color and monochrome standards; peripherally supported by process amplifiers, screen splitters, cameras, and monitors

**DATA ACQUISITION:** Manual acquisition is made from test instrumentation, spectrum analyzer, strip charts, digital oscilloscopes, logic analyzers, etc.

## TELEVISION SYSTEMS LABORATORY



# TELEVISION SYSTEMS LABORATORY FLOOR PLAN



**TELEVISION SYSTEMS LABORATORY**



S83-39716

## **General Facility Specifications**

### **TEXT AND GRAPHICS LABORATORY**

LOCATION: Building 44, Room 277

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$300k

REPLACEMENT COST: \$600k

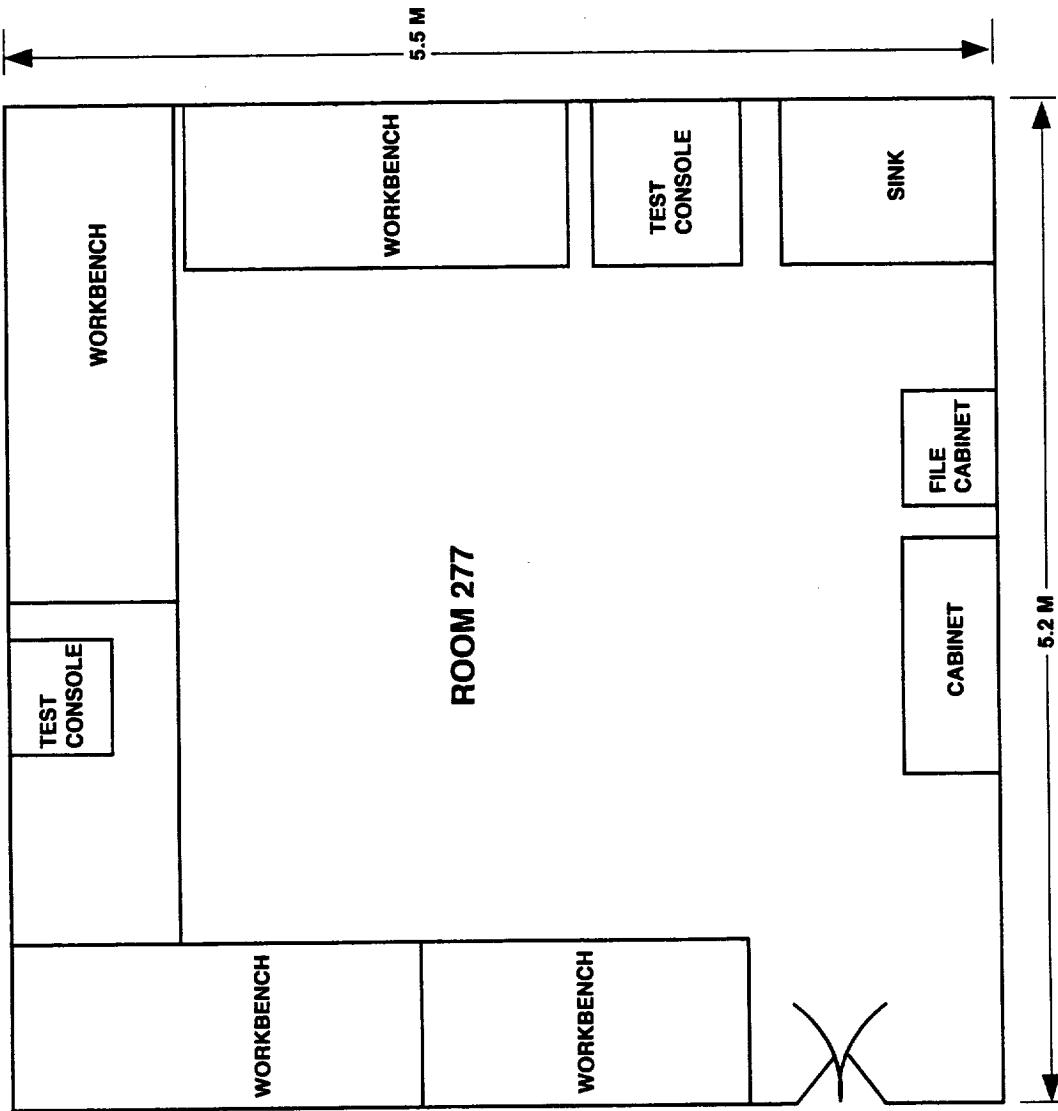
USE: The Text and Graphics Laboratory has capability for design, development, maintenance, and testing of text and graphics flight and ground support components, i.e., scanners, hardcopiers, and printers.

DESCRIPTION: The Text and Graphics System Laboratory occupies 28.4 square meters of floor space in Room 277 of Building 44 at JSC. The laboratory is equipped for

development, evaluation, testing, and maintenance of text and graphics facsimile equipment. In addition, integrated tests and demonstrations of flight hardware are performed in the laboratory, particularly to train flight crew and flight operations personnel. System evaluation tasks include measurement of resolution and modulation transfer function, determination of the output copy density capability, and determination of the optimum gamma correction. Typical tasks specific to scanners include the optical and electrical alignment and performance of acceptance tests. Tasks associated with hardcopiers are video alignment, adjustment of developer heater temperature, evaluation of the paper transport subsystems, and final checkout of flight units. Equipment supporting text and graphics system and hardware testing includes pattern generators, command generators, telemetry displays, test-point breakout panels, oscilloscopes, frequency counters, digital voltmeters, various power supplies, densitometers, logic analyzers, and other standard laboratory equipment.

DATA ACQUISITION: Manual acquisition is made from test instrumentation, logic analyzers, digital oscilloscopes, etc.

## TEXT AND GRAPHICS LABORATORY FLOOR PLAN



TEXT AND GRAPHICS LABORATORY

ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH



## General Facility Specifications

### VIDEO CASSETTE RECORDER SYSTEM LABORATORY

LOCATION: Building 44, Room 244

POINT OF CONTACT: Chief, Tracking and Communications Division, Code EE, (713) 483-2873

STATUS: Active

YEAR BUILT: 1983

INITIAL COST: \$400k

REPLACEMENT COST: \$600k

USE: The Video Cassette Recorder System Laboratory has capability for design, development, sustaining engineering, breadboard fabrication, and testing of the following: video cassette recording systems and system components such as video modulators and demodulators; control units; interface elements; power supplies; and automatic functional testing of flight-qualified recorder systems.

DESCRIPTION: This facility consists of one room (approximately 0.51 square meters) which contains two ground support equipment test consoles, a computer-operated data collection and control system, two electronics workbenches, and various cabinets and tables. The two ground support equipment consoles are identical. Each contains the following major equipment which can be interconnected in a number of configurations by means of patching and switching equipment:

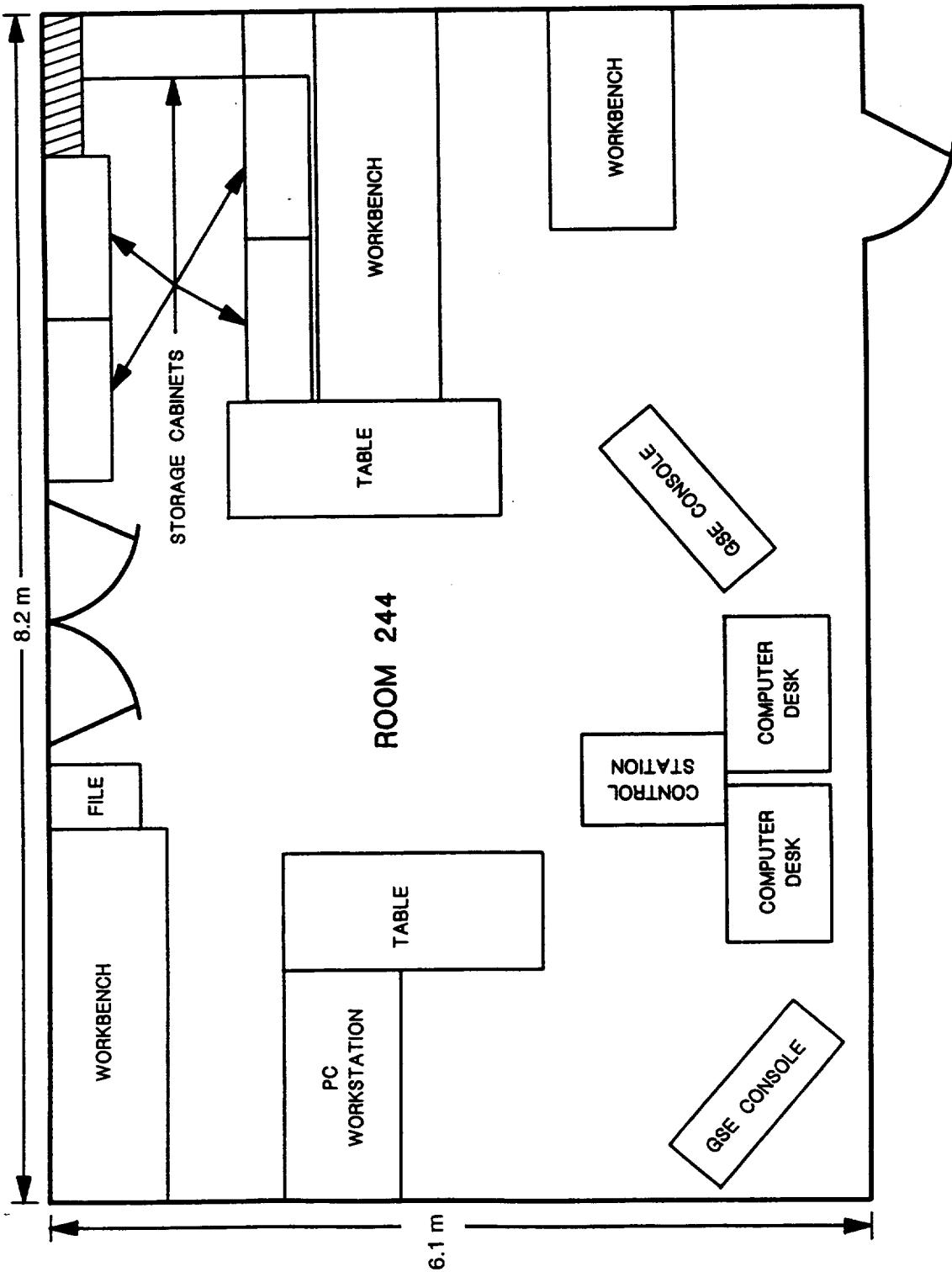
- Color and monochrome picture monitors
- Video waveform monitor
- Vectoscopes
- Video measurement set
- Programmable video signal generator
- Programmable audio distortion analyzer
- Programmable digital multimeter
- Programmable power supply
- Standard Interrange Instrumentation Group B (IRIG-B) time codegenerator and reader with automatic tape search unit
- Interface patch panel for recorder testing
- Shuttle Audio Central Control Unit Simulator

In addition to the test equipment in the ground support equipment test consoles, the laboratory contains a Tektronix Model 4052 computer, a Model 1980 answer system (an automatic video measurement system), a Tektronix Model VM100A video measurement set, and a personal computer workstation for development work. This equipment, along with suitable hardcopy units, provides complete, automatic evaluation of video signals against user or Federal Communications Commission standards. The Model 4052 computer is integrated into the system to control IEEE-488 and general purpose interface buses.

The laboratory also contains nondedicated test equipment such as waveform monitors, oscilloscopes, and digital multimeters, which are used along with the workbenches for development and maintenance work.

DATA ACQUISITION: Manual acquisition is made from test instrumentation; spectrum analyzer, strip charts, digital oscilloscopes, logic analyzers, etc.

## VIDEO CASSETTE RECORDER SYSTEM LABORATORY FLOOR PLAN



## Chapter 3

### NAVIGATION CONTROL AND AERONAUTICS DIVISION (EG)

CONTENTS	PAGE	REMARKS
FACILITY		requirements; system concept definition; statistical and dynamic system analysis; and the design, development, and verification of system hardware and software.
Electro-Optics Laboratory and Rooftop Tracking Laboratory	3-2	The EG Division monitors contractor development and production programs to ensure adherence to specified performance requirements within cost and schedule restraints.
Inertial Components Laboratory	3-6	
Inertial Systems Laboratory	3-9	Laboratory tests and test evaluations are a key step in the division's data base development and preparation for systems flight readiness and certification.

#### Overview

The Navigation Control and Aeronautics Division is responsible for the definition, development, implementation, integration, and verification of guidance, navigation, and control hardware and software systems.

It provides overall guidance, navigation, and control systems engineering and integration support for activities where the guidance, navigation, and control systems interact with other systems.

Also, the Navigation Control and Aeronautics Division is responsible for engineering in aerospace disciplines for flight dynamics, computational fluid dynamics, aerodynamics, and aerothermodynamics for spaceflight programs assigned to JSC.

While performing these responsibilities, the division engages the following engineering methods: establishment of preliminary

requirements; system concept definition; statistical and dynamic system analysis; and the design, development, and verification of system hardware and software.

The division is also required to support operations development, mission planning, mission support, and post flight evaluations of system hardware and software performance.

The division maintains an advanced development base which provides capabilities ranging from conceptual definition of guidance, navigation, and control system architectures for future missions, to the design, development, and evaluation of specific advanced components and algorithms.

To properly accomplish the preceding responsibilities, the division has developed an extensive range of physical laboratories and computational analysis tools which are generally tailored to support detailed technical analyses, development, and test activities in support of major programs such as Space Shuttle and Space Station Freedom.

## General Facility Specifications

### ELECTRO-OPTICS LABORATORY AND ROOFTOP TRACKING LABORATORY

LOCATION: Building 16A, Room 1153 and 16A Rooftop

POINT OF CONTACT: Chief, Navigation Control and Aeronautics Division, Code EG, (713) 483-8224

STATUS: Active

YEAR BUILT: 1968

INITIAL COST: \$1,250k

REPLACEMENT COST: \$3,500k

USE: The Electro-Optics Laboratory is used to test and evaluate star tracker units at both qualification and flight test levels. Test sets are designed and fabricated to provide data acquisition and analysis capabilities for star tracker output data. Comprehensive tests programs are performed with these test sets in order to verify the proper operation of the star trackers. Tests are performed both indoors using simulated stars and outdoors using real star fields.

products, and for an advanced technology database to manage the data in the laboratories.

DESCRIPTION: The Electro-Optics Laboratory activities involve the performing of complete evaluation testing of the star tracker, qualification unit, serial number 0001, including both laboratory testing at JSC and field testing at the Sam Houston State University Observatory. The laboratory is developing a Shuttle portable test set that can automatically cycle through all tests at Sam Houston State University. It also procures and integrates components for a high speed image processing workstation that can support the evaluation of advanced electro-optics sensors. The laboratory establishes and maintains a database of state-of-the-art sensor design technology for advanced technology evaluations, and it is involved in the development of a theodolite system which will accurately calibrate all future test set systems. It tests and evaluates various state-sensor designs for predefined sensor characteristics. Finally, the laboratory is integrating a new computer control system for the micro-stepper motors of the celestial mount in the Tracking Laboratory and refurbishing the position read-out displays.

Laboratory facilities are used to perform all required tasks for testing and evaluating state-of-the-art, electro-optics sensors. Software is defined and developed for candidate electro-optic sensor applications, for a high speed image processing workstation to compare and evaluate the performance of advanced sensor designs with off-the-shelf commercial

Potential activities for the laboratory include the development of a real-time Star Field Simulator with the capability to simulate star field motion with debris. This test set will support the evaluation of advanced star trackers with the capability for multiple star tracking, star identification, and attitude determination. The Electro-Optics Laboratory anticipates for FY 1993 the development and investigation of Advanced

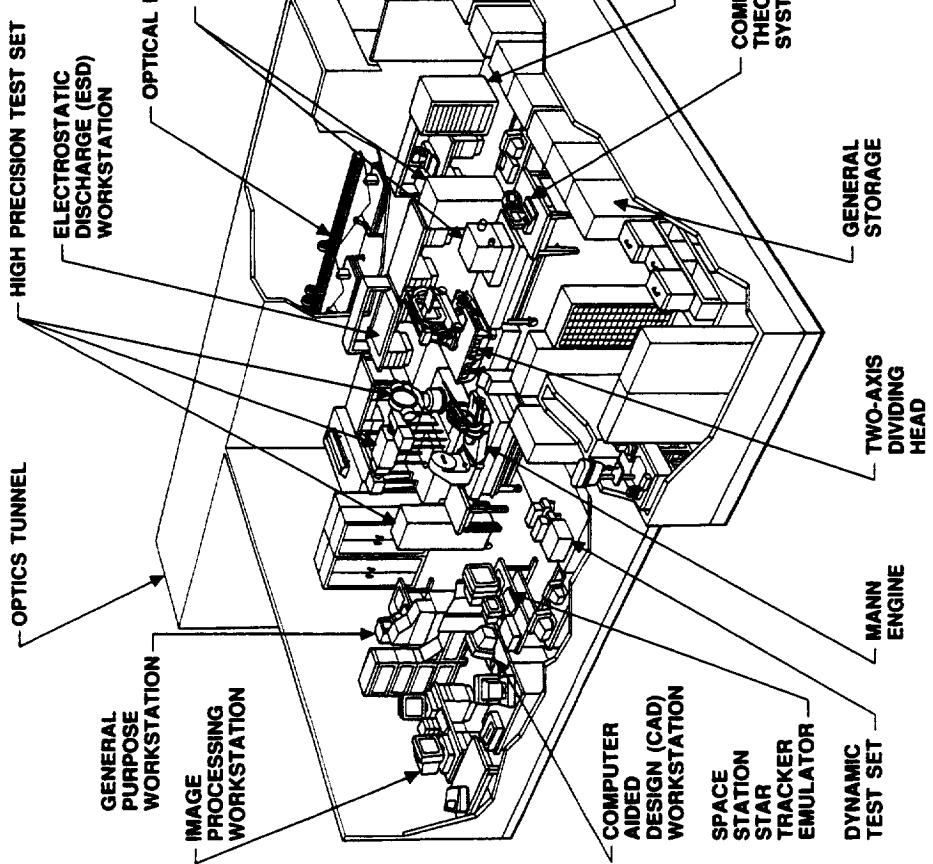
**Technology Sensor Evaluation** to continue with the test and evaluation of state-of-the-art sensor designs for predefined sensor characteristics and for unique space vehicle applications.

The Electro-Optics Laboratory contains six specialized optical test sets, measurement stations, calibration systems, and optical alignment workstations. This test hardware equipment is supported by multiple personal computer-based emulators, computer-aided design stations, graphics stations, and electrostatic discharge protected, Type 1 workstations. This hardware and test equipment is contained in an area of 225 square meters. Engineering support for the laboratory is located in three offices which between them contain a total of twenty-seven square meters. Each office area contains personal computers to support the engineering analysis of

optical components and systems. Equipment inventory listings for the laboratory and the two office areas are available.

**DATA ACQUISITION:** The Electro-Optics Laboratory workstations are linked by modem and local area network to both JSC and remote engineering facilities. Information pertinent to laboratory test programs can easily be located and downloaded to JSC via these interfaces. Laboratory test sets contain sophisticated data acquisition systems which serve to capture important test data for analysis and evaluation purposes. An advanced technology database has been developed to support the archiving of emerging technology information for possible future space applications. Data packs are developed during tracker evaluations and are transmitted to interested customers and support contractors.

## ELECTRO-OPTICS LABORATORY



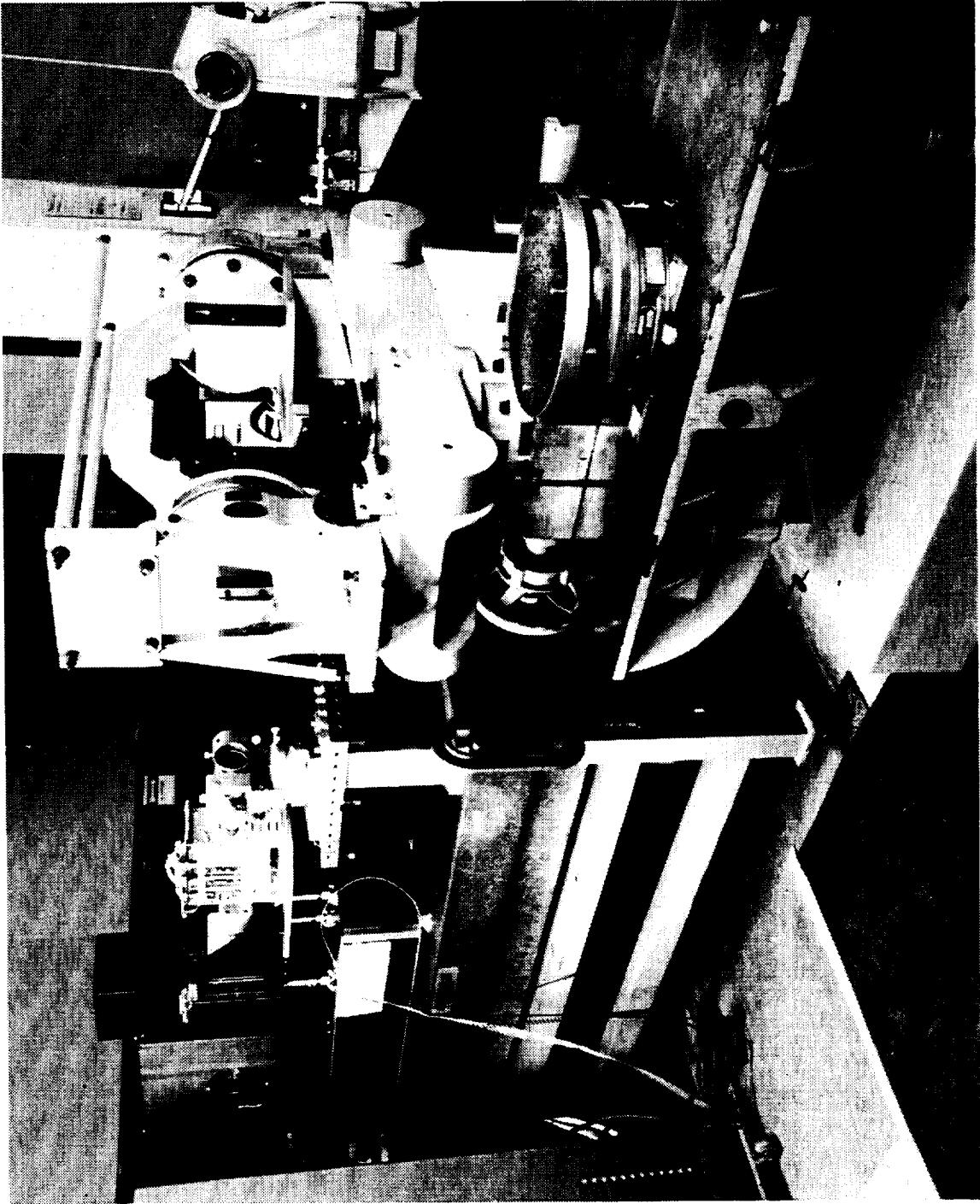
## PRIMARY ACTIVITIES

1. High precision test set development
2. Space Station star tracker emulator development
3. Image processing workstation development
4. Tracking laboratory display and control system upgrade
5. Computer aided theodolite system development
6. Space Shuttle star tracker qualification and flight unit evaluation
7. Advanced technology sensor evaluation
8. Advanced technology data base development
9. Dynamic test set development

**SHUTTLE STAR TRACKER BORESIGHT TEST FIXTURE**

**ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH**

S91-49663



## General Facility Specifications

### INERTIAL COMPONENTS LABORATORY

LOCATION: Building 16A, Rooms 1169 and 1169A

POINT OF CONTACT: Chief, Navigation Control and Aeronautics Division, Code EG, (713) 483-8224

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$900k

REPLACEMENT COST: \$2,700k

USE: The Inertial Components Laboratory is used to test and evaluate state-of-the-art candidate inertial sensors and systems for use as inertial measurement and reference devices on manned and robotic space vehicles, experiments, and pay-loads. The laboratory develops specifications, hardware, and software for the test, calibration, and evaluation of inertial sensor systems for implementation on flight robotics and experiments.

DESCRIPTION: The Inertial Components Laboratory performs complete evaluations of the Space Station Freedom Inertial Sensor Assembly and its Component Development Unit. The laboratory develops and evaluates sensor packages for the Flight Data Systems Division, Applications Branch (EK6), and the Automation and Robotics Division, Flight Robotics Systems Branch (ER31). Documentation activities include the update of the state-of-the-art inertial sensor documentation, the survey of

inertial sensors for JSC applications, and the development of operation and test procedures for evaluating inertial sensors on the upgraded Goertz two-axis Inertial Test Table. Evaluation and calibration software requirements and procedures are developed for the EK and ER Divisions' flight equipment development support.

The laboratory has the capability to perform evaluations of the following: the latest generation Litton ZLG Inertial Navigation System; the Honeywell Global Positioning System and Inertial Navigation System; the Vibrating Beam Accelerometer; the Resonating Beam Accelerometer and Rate Transducer; and the Honeywell Fiber Optic Gyros.

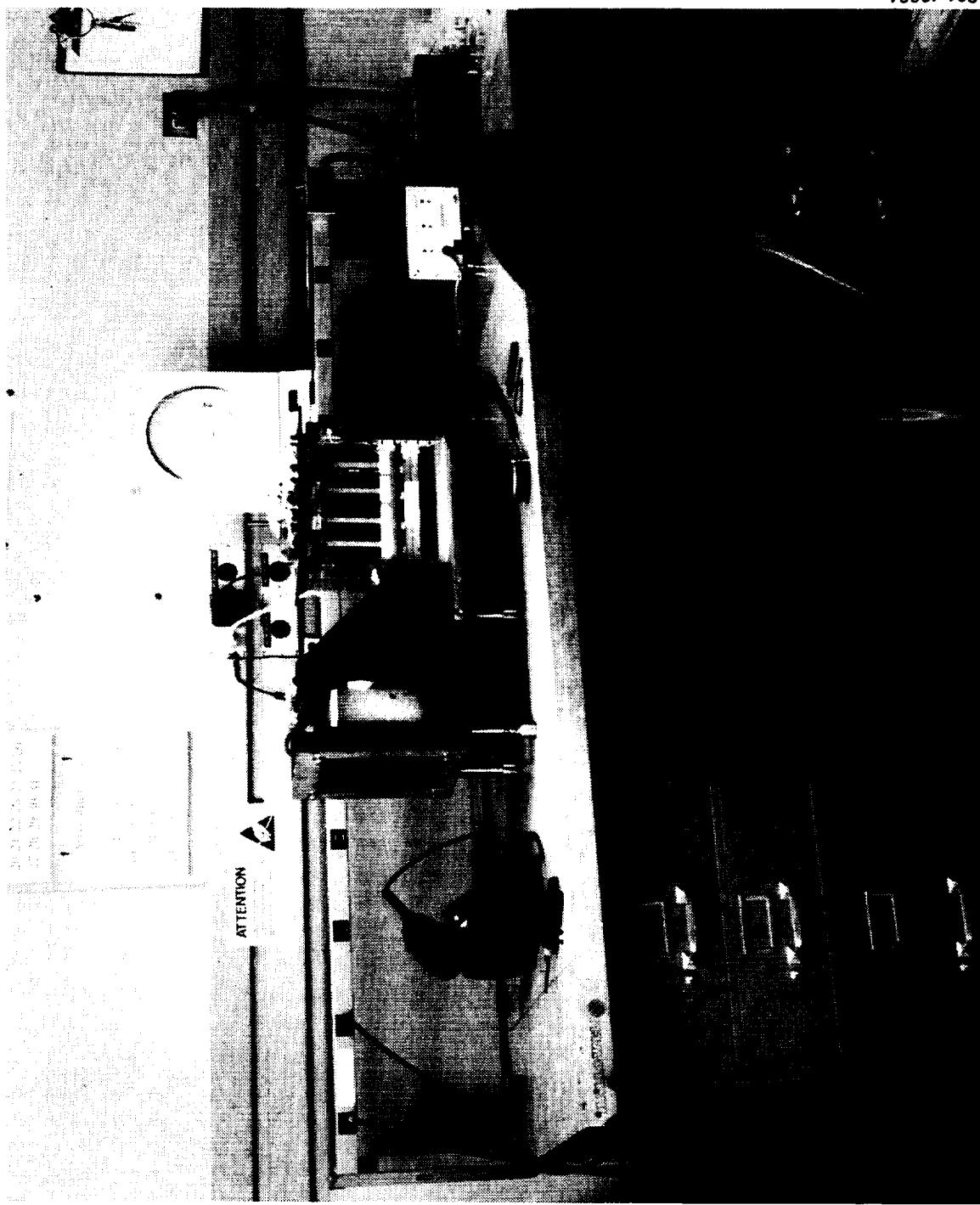
The Inertial Components Laboratory provides preflight and post flight calibration and evaluation of the Simplified Aid for Extravehicular Rescue inertial sensor packages and the Microgravity Measuring Device of the Wake Shield Facility. It also provides for the evaluation of miniature Ring Laser Gyro devices and FOG Inertial Navigation Systems for application to meet tactical grade inertial requirements which will be determined along with inertial grade Global Positioning System and Inertial Navigation System evaluations.

The Inertial Components Laboratory contains the following equipment supported by multiple personal computer-based command and data acquisition computer systems: two two-axis specialized inertial rate tables; components analysis hardware; and test equipment. The hardware and test equipment is

contained in an area of 191 square meters and a laboratory air lock of 7.1 square meters. Engineering support for the Inertial Components Laboratory is located in two offices which between them have a size of 14.9 square meters. Each office area contains personal computers to support the engineering analysis of inertial components and systems.

DATA ACQUISITION: The Inertial Components Laboratory personal computers are interfaced to custom built data acquisition hardware to collect, store, and transmit test performance data collected from candidate inertial sensors. Links are provided to perform additional engineering evaluations in other workstations or for data dissemination to interested customers.

## ELECTROSTATIC DISCHARGE WORKBENCH



S91-49664

## **General Facility Specifications**

### **INERTIAL SYSTEMS LABORATORY**

**LOCATION:** Building 16A, Rooms 1020 and 1022

**POINT OF CONTACT:** Chief, Navigation Control and Aeronautics Division, Code EG, (713) 483-8224

**STATUS:** Active

**YEAR BUILT:** 1970

**INITIAL COST:** \$1,500k

**REPLACEMENT COST:** \$5,000k

**USE:** The Inertial Systems Laboratory contains specialized analysis hardware and test equipment applicable to inertial components and inertial systems. Multiple computer systems are available to support all test and evaluation activities.

**DESCRIPTION:** The Inertial Systems Laboratory is a hardware and software, configuration-controlled environment that supports fully documented Inertial Navigation System flight qualification testing, flight performance monitoring, anomaly troubleshooting, and repair activities. Year-to-year laboratory activities retain a degree of flexibility in order to support the developing needs of the spaceflight program. Current and scheduled work includes the qualification testing of eight new or refurbished inertial navigation systems to support eight Shuttle planned orbiter missions. The qualification testing process applies twelve periodic testing sequences as described and required by the

Operations and Maintenance Requirements and Specifications Documentation. Inertial system troubleshooting and repair activities are on an as-required basis, dependent upon Kennedy Space Center Logistics funding.

Support of each of the eight planned orbiter flights requires final flight worthiness acceptance tests of new or refurbished inertial navigation systems and periodic calibration sequences as specified by the Operations and Maintenance Requirements and Specifications Documentation. Support to the eleven Shuttle missions scheduled for FY 1993 will include troubleshooting, and repair activities could include the final preparation and complete Acceptance Test Procedures on High Accuracy Inertial Navigation System units not yet completed by the manufacturer. Additional troubleshooting would probably, based on history, cover three or four failures on-orbit. Those inertial units not designated as flight spares would be subject to a periodic operation sequence, and there could be as many as sixteen of these sequences.

Laboratory activities encompass hardware and software development and maintenance, feasibility and engineering trade-off studies, analyses, surveys, literature researches, technical document reviews, development of procedures, laboratory testing, and data reduction and analysis.

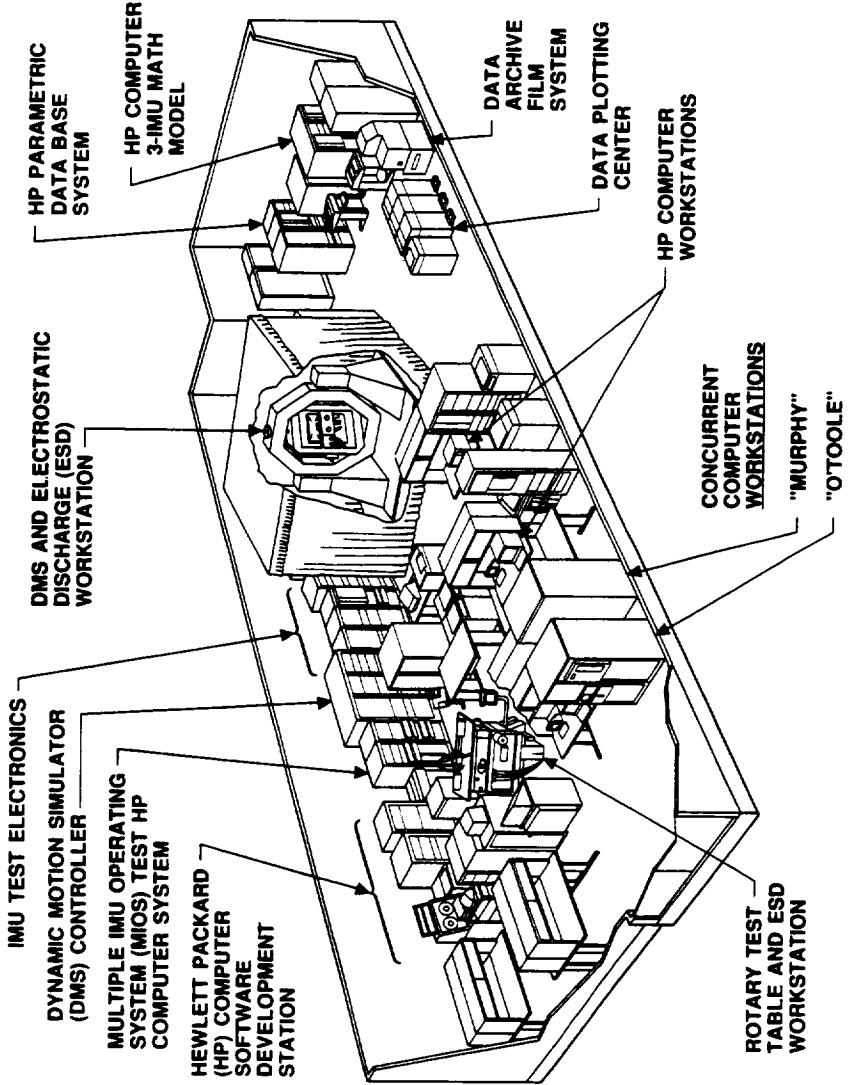
The hardware and test equipment is contained in an area of 174 square meters and a laboratory air lock of seventeen square meters. Engineering support for the Inertial Systems Laboratory

is located in two offices which together have a size of forty-eight square meters. Each office area contains multiple personal computers to support the engineering analysis of inertial components and systems. Equipment inventory listings for each of the three areas are available.

DATA ACQUISITION: The Inertial Systems Laboratory contains the only complete KT-70/HAINS parametric database which is available to the NASA or the inertial measurement unit

community. The database contains all of the manufacturer's Pre-Acceptance Test Procedure, Acceptance Test Procedure and troubleshooting data, Inertial Systems Laboratory flight worthiness test data and troubleshooting data, and the mission flight data from pre-launch through touchdown. The database is sustained via hardcopy and electronic data inputs from the manufacturer, Kennedy Space Center Guidance, Navigation and Control Section, Inertial Systems Laboratory testing, testing performed at other locations, such as Palmdale, California, and the on-orbit data available at the Mission Evaluation Room.

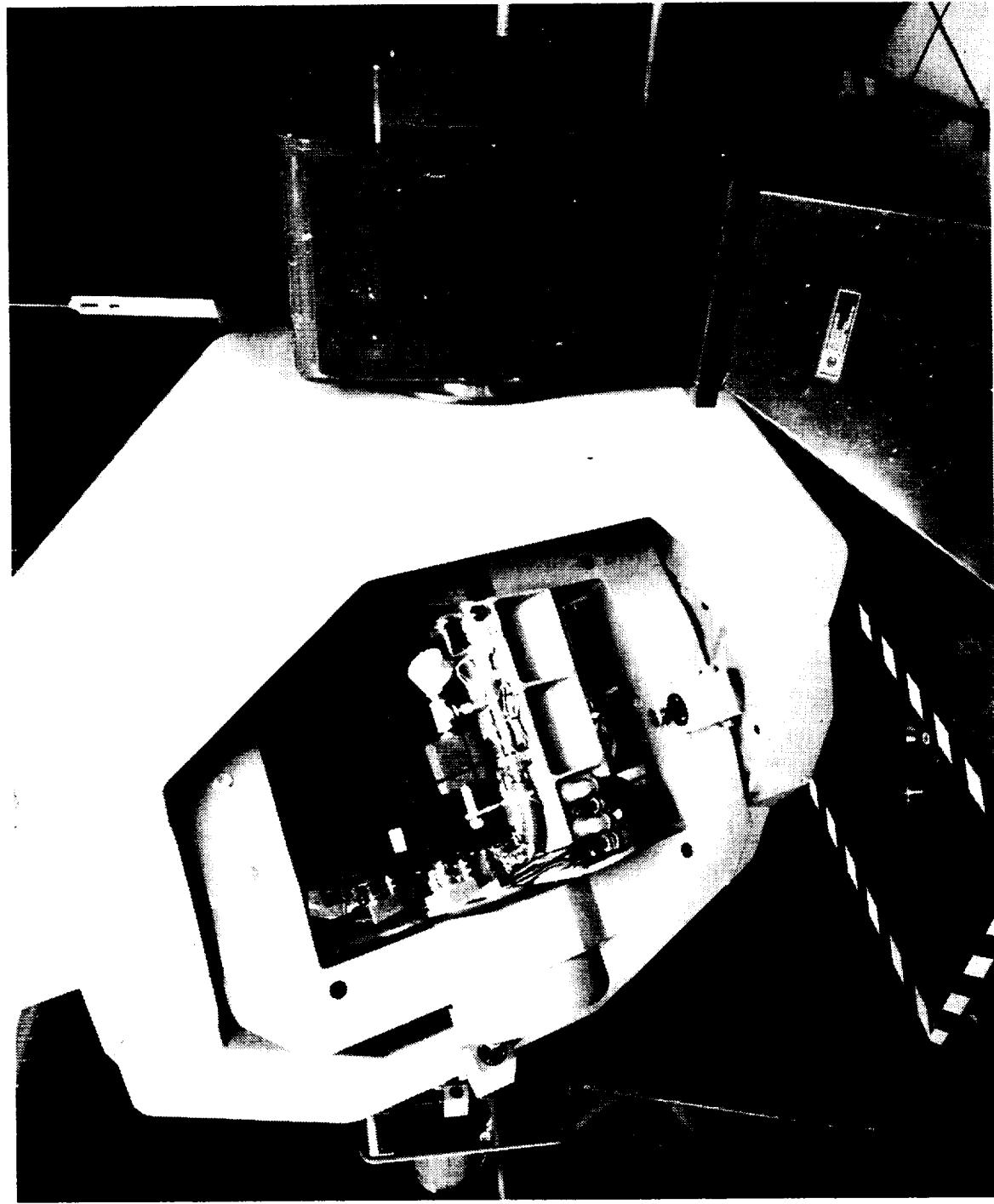
## INERTIAL SYSTEMS LABORATORY



## PRIMARY ACTIVITIES

1. Flight qualification of inertial measurement units (IMU's)
2. Maintenance of Shuttle IMU parameter data units
3. Analysis of IMU performance anomalies
4. Shuttle IMU prelaunch performance monitoring support
5. Support of Shuttle Avionics Integration Laboratory (SAIL) operations
6. Test and analysis of state-of-the-art inertial navigation systems

**DYNAMIC MOTION SIMULATOR WITH TWO KT 70 IMUS UNDER CALIBRATION**



S91-49666

## **Chapter 4**

### **FLIGHT DATA SYSTEMS DIVISION (EK)**

#### **Contents**

#### **Overview**

FACILITY	PAGE	The Flight Data Systems Division is responsible for the definition, development, implementation, integration, verification, and maintenance of flight hardware and software data systems that provide onboard computation and information processing, onboard checkout, data storage, instrumentation, and displays and controls for manned spaceflight programs assigned to JSC.
Shuttle Avionics Integration Laboratory .....	4-2	Overall engineering and integration support is provided for data systems' interactions with other systems. In addition, the division is responsible for the development of software life cycle management tools; the planning and design of software development facilities; the development and maintenance of applications codes used in those facilities; and the definition, development, implementation, and integration of flight hardware and software verification facilities wherein the Flight Data Systems Division performs integrated systems verification.
JSC Avionics Engineering Laboratory .....	4-9	
Modular Auxiliary Data System Instrumentation Laboratory .....	4-14	
Software Development Facility .....	4-17	
Microprocessor Laboratory .....	4-20	
Flight Tape Recorder Laboratory .....	4-24	
Instrumentation Laboratory .....	4-27	
Displays and Controls Laboratory .....	4-32	
Real-Time Systems Engineering Laboratory .....	4-36	
Space Station 1553 Local Bus Test Bench .....	4-39	
Time Generation System Testbed .....	4-41	
Multiplexer/Demultiplexer and Orbiter Data Bus Test Laboratory .....	4-43	
Computing Facility .....	4-45	

## General Facility Specifications

### SHUTTLE AVIONICS INTEGRATION LABORATORY

LOCATION: Building 16-16A, West High Bay

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1974

INITIAL COST: \$425M

REPLACEMENT COST: \$630M

USE: The Shuttle Avionics Integration Laboratory performs integrated avionics systems verification for Space Shuttle hardware and software including both open-loop systems testing and closed-loop testing with simulated vehicle dynamics.

DESCRIPTION: The Shuttle Avionics Integration Laboratory is a central facility where avionics and related flight hardware (or simulations of the hardware), flight software, flight procedures, and associated ground support system equipment are brought together for integration and mission verification testing. Integration testing includes both open-loop integration systems testing and closed-loop testing with simulated vehicle dynamics. The central facility consists of two primary areas: the Shuttle Test Station and the Guidance, Navigation, and Control Test Station.

Shuttle Test Station

The Shuttle Test Station is the primary test station of the laboratory and is configured to provide a full testing capability for all mission flight phases and Launch Processing System prelaunch activities. The flight system essentially consists of a full-ship set of avionics hardware, including a cockpit with forward and aft stations and flight-type wiring. Propulsion systems and aerodynamic control systems are simulated to compute forces, moments, fuel consumption, and associated mass and inertial changes. The avionics hardware is mounted in the Shuttle Test Station using flight-type equipment bays and shelves. These bays are located similarly to those in the orbiter and are connected by the flight wire harnesses.

The Shuttle Test Station provides a full-scale cargo bay equipped with simulated support rails and avionics interface connections located to accommodate payloads of full size and weight. Standard orbiter and payload power system interfaces are also included in the Shuttle Test Station.

The Test Operations Center provides the central control facility for test operations for the Shuttle Test Station. The center contains hardware and software for the acquisition, processing, displaying, and recording of test data transmitted from the avionics system or simulation system during a test sequence. The center also provides the capability to insert faults during a test sequence. The data processing and display system

provides test engineers the capability for real-time data monitoring and review.

The Launch Processing System, consisting of automated control and monitor functions for the Space Shuttle avionics systems, provides the laboratory with the capability to support the Launch Processing System and Shuttle vehicle interface hardware plus vehicle utility software verification, Shuttle vehicle mission testing, Kennedy Space Center launch countdown sequence programs, and evaluation of selected Launch Processing System applications programs.

The Shuttle Dynamics Simulator provides the simulation of environment, aerodynamics, vehicle dynamics, flight sensors, scene generator drive, and remote manipulator system. The Shuttle Dynamics Simulator also provides an interface system for data transmission between the flight system and Vehicle Dynamics Simulation with a secondary link to the Test Operations Center. The Vehicle Dynamics Simulator has the capability to insert faults into certain sensors and functions in the simulation.

The Payload Avionics Test Station provides the Shuttle Avionics Integration Laboratory with a payload simulation capability adequate for the verification of flight system payload-unique hardware and software. The Payload Avionics Test Station is composed of a general-purpose computer, digital and analog input and output devices, specialized payload hardware emulators, cables, and flight system interface panels. The Payload Avionics Test Station is designed to facilitate mission-by-mission laboratory configurations dictated by the widely varying payload interface requirements.

The Verification Test Station produces quick-look reports in near real time to support the rapid assessment of the laboratory's verification test runs. Quick-look reports are produced that analyze critical pulse coded modulation and environmental-specified criteria.

The Space Shuttle mated elements include orbiter, external tank, solid rocket booster, and Shuttle main engines. The propulsion elements are simulated in the Shuttle Avionics Integration Laboratory by a Marshall Mated Elements System. The system provides a mix of flight avionic hardware, flight software, flight wire harnesses, and simulations to verify the functional operation of the Space Shuttle mated elements in the laboratory's simulated mission environment. The Marshall Mated Elements System also has the capability to insert faults into certain sensors and functions in the propulsion system.

The Shuttle Avionics Integration Laboratory may interface with the Electronics Systems Test Laboratory via radio frequency and hard-line. Joint tests, using both of these laboratories, provide the capability for final demonstration of flight hardware and software interface compatibility using all radio frequency system interfaces between the Shuttle orbiter and ground stations, relay satellites, detached payloads, and extravehicular activity communications terminals. The Electronics Systems Test Laboratory is located in Building 44 at JSC. It is the primary communications and tracking system verification test facility for the Space Shuttle program.

Ground support equipment and special test equipment in the Shuttle Avionics Integration Laboratory include the capability to troubleshoot and locate problems at the Flight System Line

Replaceable Unit level, load flight software, access the Flight System data buses and electrical interfaces, insert faults, and operate the Flight System in a single-string configuration.

Example equipment includes the Shuttle Avionics Test Set, Navigation Aid Stimulator, and breakout and breakthrough boxes.

#### Guidance, Navigation, and Control Test Station

The Guidance, Navigation, and Control Test Station provides the Shuttle Avionics Integration Laboratory with a flight hardware certified, high-fidelity test facility for development and verification of the Shuttle Avionics core hardware and software. The Test Station includes a forward cockpit consisting of the commander side only and no aft station. The system operator is an Orbiter General Purpose Computer redundant set configuration running independently of other Shuttle Avionics Integration Laboratory or Shuttle Engineering Simulation simulators. Minimum shared equipment consists of a wideband patch to the Launch Processing System and T-0 umbilical (i.e., "T-0" refers to the simulation of the umbilical separation at launch). The avionics hardware are mounted on fabricated metal racks with prototype liquid cooling plates or forced air conduits according to flight type Shuttle systems design. The test operation area provides work stations, recorders, displays, and electronic interfaces to support the required test operation control functions for the Guidance, Navigation, and Control Test Station. The mode control provides laboratory timing and supports stand-alone, off-line operations and interface verification. It generates electrically compatible Real-Time Operations Mode interrupts: initial conditions time, operations time, freeze and interval time (twenty milliseconds), and all mode state discrete. The Shuttle Avionics Test Set interfaces with the avionics data processing

system and allows for moding and computer controlled loading, starting, and stopping of the data processing system with other elements of the Guidance, Navigation, and Control Test Station.

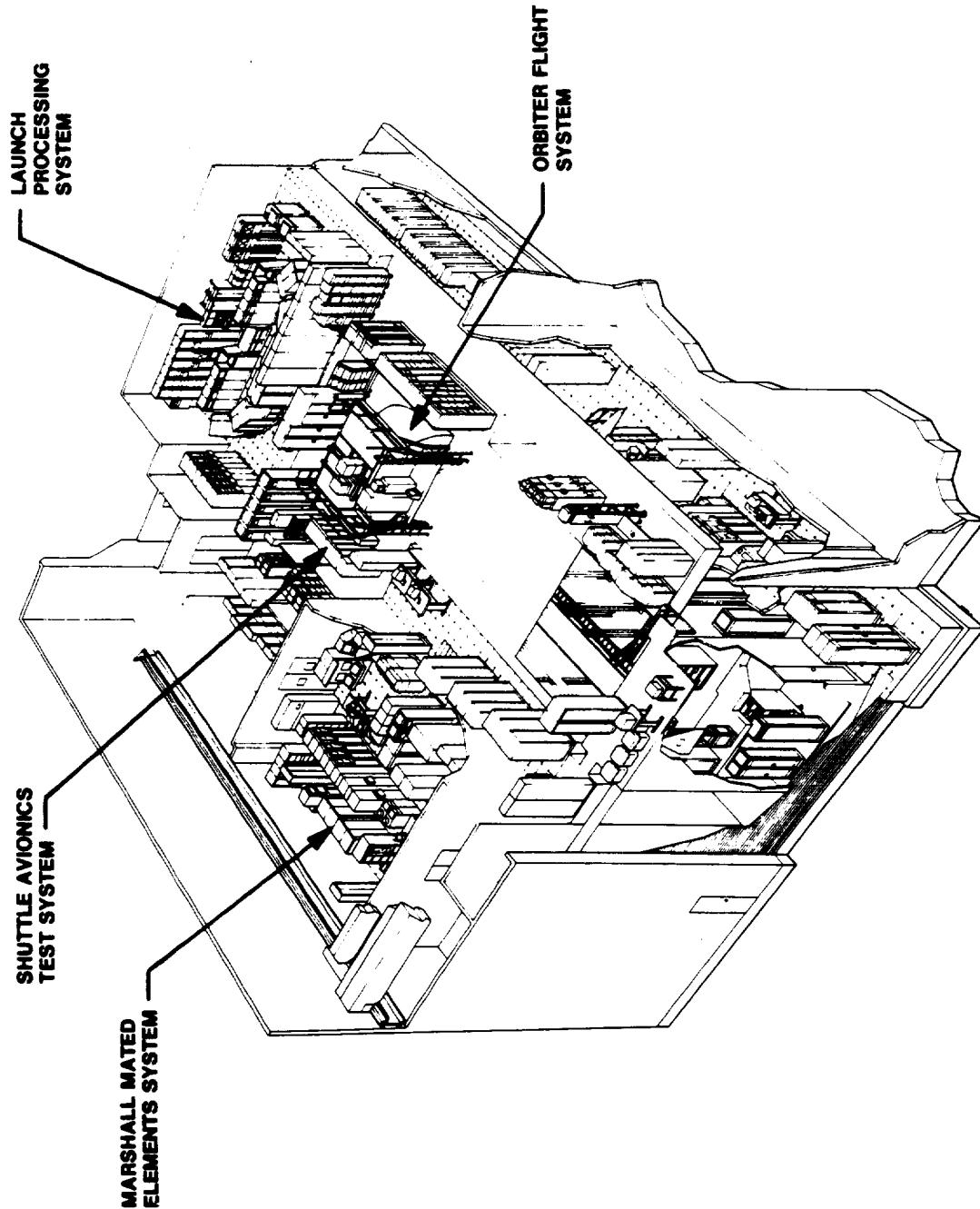
Peripheral Systems used during test operations are the following: Electrical Power Distribution System, Facility Caution and Warning, Timing, and Intercom. Launch Processing System T-0 patch capability and a Poly 2000E generator are shared with the Shuttle. The Flight System to Environment System Interface provides the flight system with simulated data bus, math modeled nonavionics, flight control, and guidance and navigation data from the Environment and Dynamics Simulation. The Shuttle Avionics Integration Laboratory utilizes the following equipment:

Type of equipment	Quantity
Gould NP-1 Computer	1
SEL 32/97 Computers	5
SEL 32/87 Computers	2
SEL 32/67 Computers	4
SEL 32/77 Computers	6
SEL 32/75 Computers	6
SEL 32/55 Computers	4
Encore 2040 Computer (Seahawks)	1
Raytheon P-704 Computer	1
Motorola Computers	2

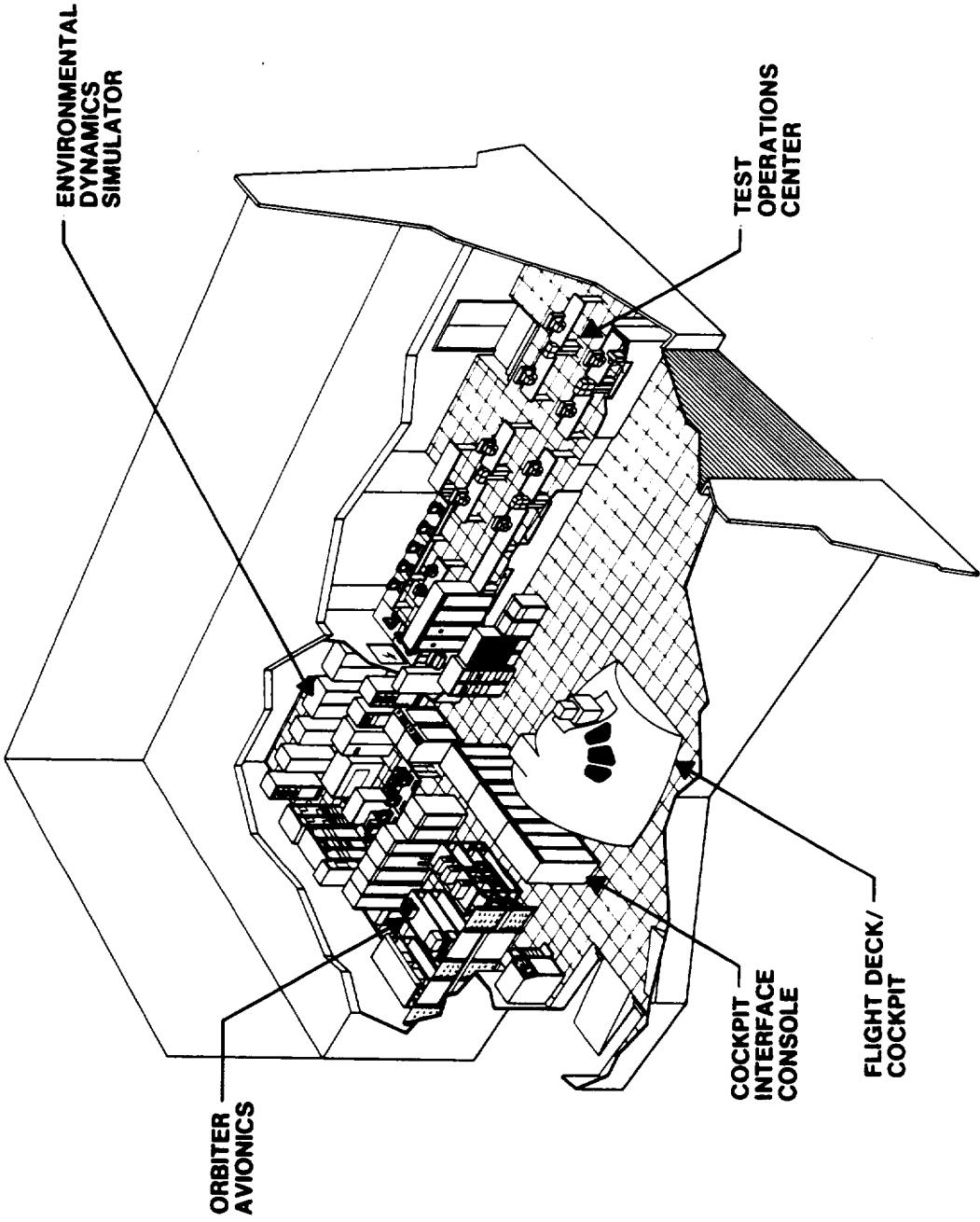
**DATA ACQUISITION:** The presentation of Shuttle Avionics Integration Laboratory data is multifold. The astronaut crew is presented data via analog and digital meters, cathode ray tube displays, scene generators, and the usual complement of Shuttle displays and controls (lighted push-buttons, annunciators, voice, etc.). Data are presented to Shuttle Avionics Integration Laboratory test controllers via digital terminals, strip chart recorders, X-Y plotters, analog and digital media including digital computer tapes, strip chart recordings, X-Y plots, floppy disks, optical disks, hard disks, hard copies of terminal displays, computer printouts, and analog instrumentation recordings (including pulse code and frequency modulation modes). A list of equipment utilized for Shuttle Avionics Integration Laboratory data acquisition is delineated in the table prior to this section.

Type of equipment	Quantity
RCS/OMS Simulators	2
Shuttle Actuator Simulator	1
Aydin Consoles	17
Integraph Consoles	10
Sun Workstations	2
Computer Terminals	71
Card Readers	3
Digital Tape Units	56
Analog Tape Units (FR3030)	6
Three Hundred Megabyte Disk Drives	16
Ten Meg Byte Disk Drives	8
Line Printers	18
Teletypes	9
Floppy Disk Drives	8
Optical Disks	4
X-Y-Plotters	4
Strip Charts Recorders	31
Hard Copiers	10
Closed Circuit Televisions	24
Time Code Readers	15
Time Code Generators	5
Central Control Units	5
Intercom Boxes	49

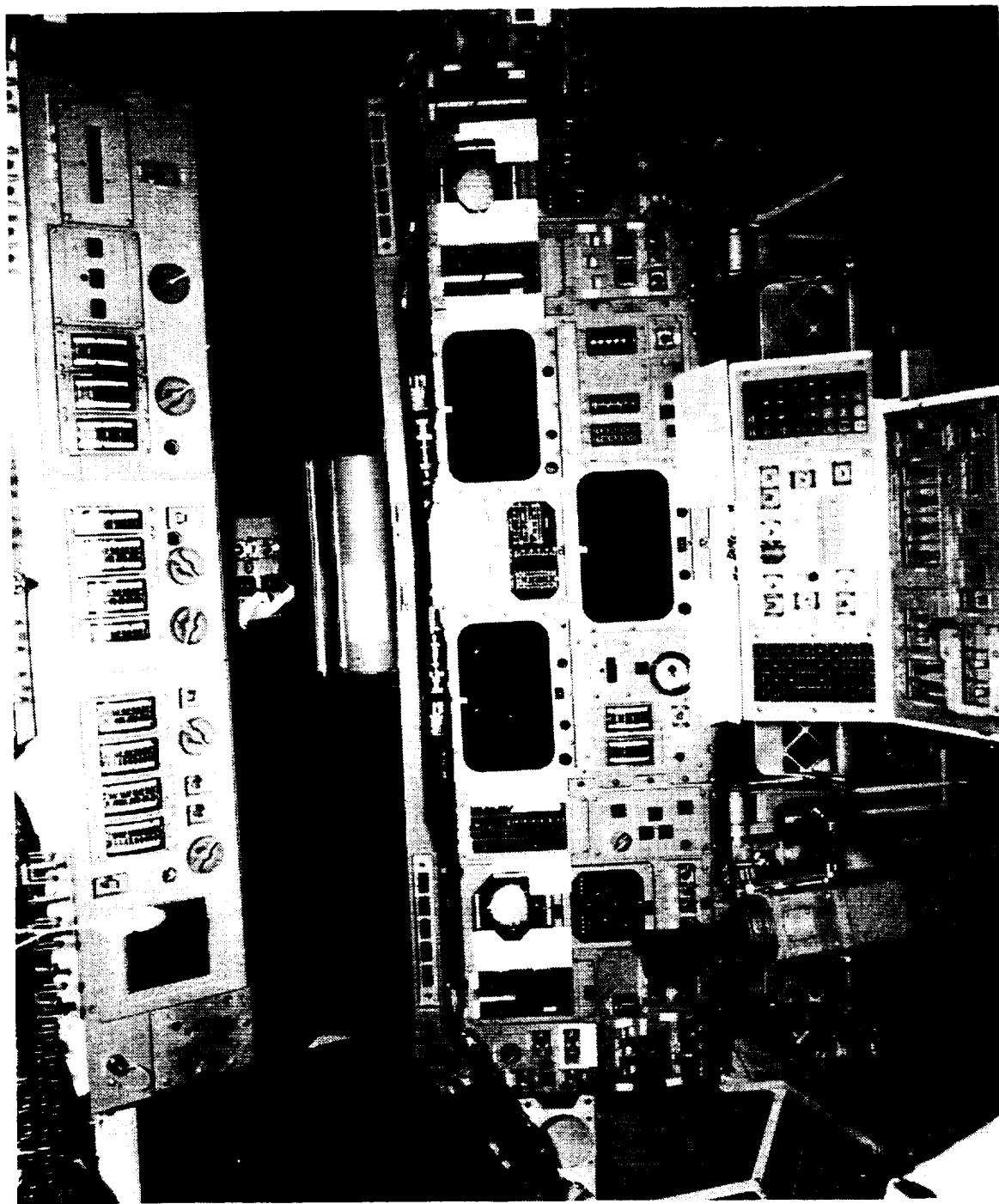
## SHUTTLE TEST STATION



**GUIDANCE, NAVIGATION, AND CONTROL TEST STATION**



## SHUTTLE COCKPIT FORWARD STATION



S79-34366

## **General Facility Specifications**

### **JSC AVIONICS ENGINEERING LABORATORY**

LOCATION: Building 16A, Room 1026

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1985

INITIAL COST: \$10,000k

REPLACEMENT COST: \$11,000k

USE: The JSC Avionics Engineering Laboratory provides  
orbiter simulations, general purpose computer testing, data  
processing system anomaly resolution, engineering tests of  
flight line replaceable units hardware and software, and  
hardware and software development support.

DESCRIPTION: The JSC Avionics Engineering Laboratory, a  
host laboratory for Shuttle avionics engineering and  
development projects, is specifically designed to aid the  
engineer in testing Shuttle avionics hardware and software in a  
realistic Shuttle data processing environment. The laboratory  
also provides support for specialized avionics testing and  
Shuttle flight simulations.

The Avionics Engineering Laboratory has provided extensive  
technical support to the Shuttle avionics engineering discipline

involving both flight hardware and software activities. One very  
significant use of the laboratory has been to provide integration,  
testing, and burn-in support for the Shuttle's new general  
purpose computers, flown on STS-37 for the first time in April  
1991.

STATUS: The laboratory has the following functions, as discussed under  
each individual heading below:

#### Open Loop Simulations

Open loop simulations can test Shuttle general purpose  
computers using a realistic, prerecorded flight environment.  
This system can also record the laboratory's closed loop  
simulator data for playback and further analysis.

#### Closed Loop Simulator

Closed loop simulations offer the most flexible use of the  
environment in the laboratory. The more critical elements of the  
Shuttle avionics system can be tested under variable conditions  
with this simulator by simulating ascent, entry, and abort modes  
of Shuttle Flight Control System software. This capability not  
only permits engineering evaluation of new software releases  
but also allows for stress testing of new avionics hardware in a  
realistic environment.

**Data Processing System Testbed**

The Data Processing System Testbed emulates the Shuttle avionics flight hardware and software systems. It also includes various laboratory support equipment systems for Shuttle avionics. The most significant of these systems is the Host Upgrade Biprocessor. This system monitors and controls up to a full complement of Shuttle general purpose computers during special testing and laboratory simulations.

**Downlist Support System**

The Downlist Support System consists of real-time displays and data archiving of the Shuttle Data Processing System data. Information is displayed in engineering units on a graphics workstation for test monitoring and anomaly investigation. Downlist data is archived and post-processed for system analysis and performance evaluation. The Downlist Support System is similar in function to Mission Control's real-time telemetry displays and to the Orbiter Data Reduction Center data archiving and processing.

**Specialized Avionics Testing**

The wide array of avionics and support equipment facilitates many types of stand-alone and specialized test projects. A prime example is the use of the Shuttle's new general purpose computers in an interconnect mode in support of Shuttle Avionics Integration Laboratory test operations. The JSC Avionics Engineering Laboratory also performs burn-in of the new general purpose computers prior to their release for flight or flight-related activities. Other special testing in this laboratory has contributed significantly to data processing system flight

hardware and software design changes and debugging support. Future project plans include confidence testing of enhanced avionics equipment and transparency testing. The laboratory will host the Multifunction Electronic Display System Development Testbed, as well as provide support for various troubleshooting and test activities.

**Laboratory Support Facilities**

The JSC Avionics Engineering Laboratory has a data and documentation library in addition to a full complement of laboratory electronics test and troubleshooting equipment that support the broad array of technical, quality assurance, and test and operations activities.

**Backup Flight System**

During an actual Shuttle flight, there is the remote possibility of failure of the four Primary Flight System computers that control the Shuttle. In that event, General Purpose Computer #5 has been designated as the backup computer. It is loaded and ready to be engaged if needed. Many simulation tests have been performed in the laboratory to determine the point in flight where the Backup Flight System would experience trouble or even fail in assuming control. These tests are currently being evaluated, and further testing may be warranted.

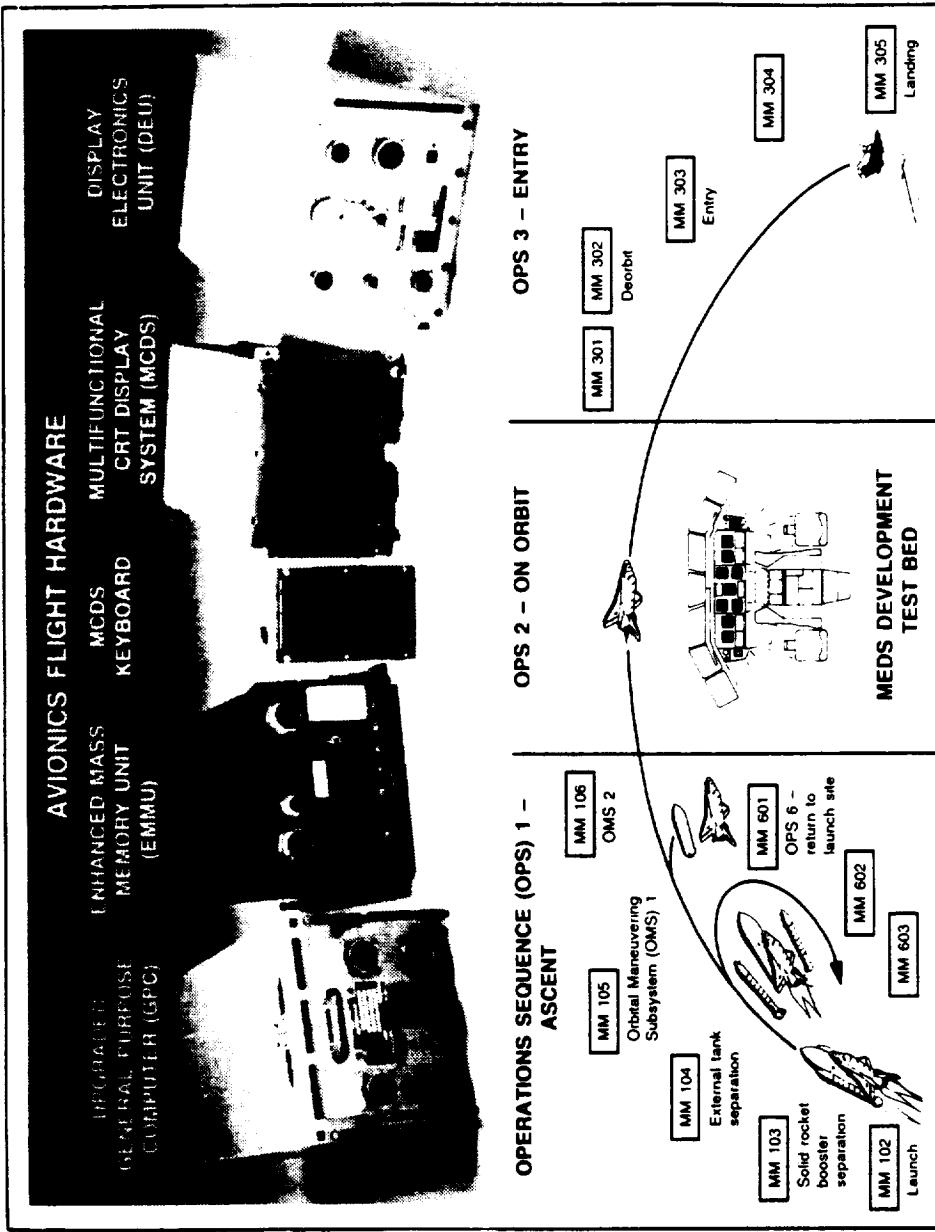
**Primary Activities**

In summary, the JSC Avionics Engineering Laboratory performs the following activities:

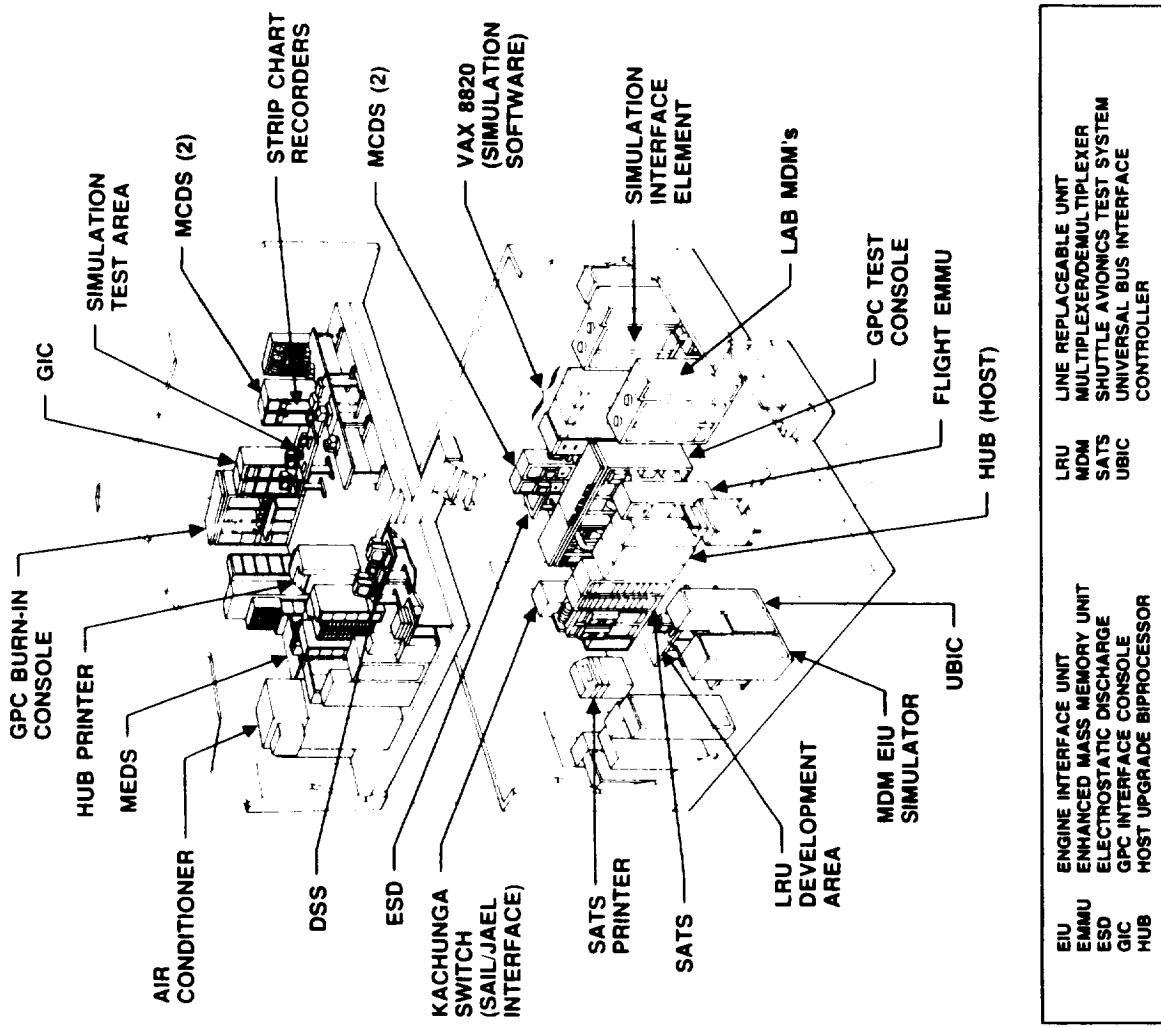
- General purpose computer upgrade testing
- Shuttle Avionics Integration Laboratory and JSC Avionics
- Engineering Laboratory interconnect testing
- Closed loop software and hardware engineering testing
- Data Processing System anomaly resolution investigations
- Avionics hardware testing
  - General purpose computer
  - Enhanced mass memory unit
  - Enhanced multiplexer and demultiplexer
  - Enhanced master events controller
  - Multifunction Electronic Display System
- Downlist Support System
  - Recording
  - Playback

DATA ACQUISITION: Data are acquired in the JSC Avionics Engineering Laboratory via several devices and methods. Strip chart recorders, digital computer tapes, direct access storage devices (hard disks), digital and analog meters, computer terminals, analog instrumentation recorders, a Shuttle downlist processing system (Loral System 500) for decommutation of JSC Avionics Engineering Laboratory and Orbiter Data Reduction Center generated data, and oscilloscopes are all used in the data acquisition and archiving process in the laboratory.

## MAJOR MODE PROFILES OF SHUTTLE MISSION SIMULATIONS



## JSC AVIONICS ENGINEERING LABORATORY OVERVIEW



## General Facility Specifications

### MODULAR AUXILIARY DATA SYSTEM INSTRUMENTATION LABORATORY

LOCATION: Building 16A, Room 2115

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1969

INITIAL COST: \$300k

REPLACEMENT COST: \$500k

USE: The Modular Auxiliary Data System Instrumentation  
Laboratory plays back flight tapes after each Shuttle mission for  
identification of instrumentation failures and anomalies (sensors  
or line replaceable units).

DESCRIPTION: The Modular Auxiliary Data System  
Instrumentation Laboratory, located in Building 16A, Room 2115,  
consists of six racks of equipment converted from a larger  
compliment of racks and equipment used to support the  
Shuttle's Development Flight Instrument System.

The Modular Auxiliary Data System is an onboard  
instrumentation system that measures and records selected  
pressures, temperatures, strains, vibrations, and event data to  
determine the orbiter's response to its environments during

flights. This data is only recovered by dumping the flight  
recorder to ground recorders, post-flight.

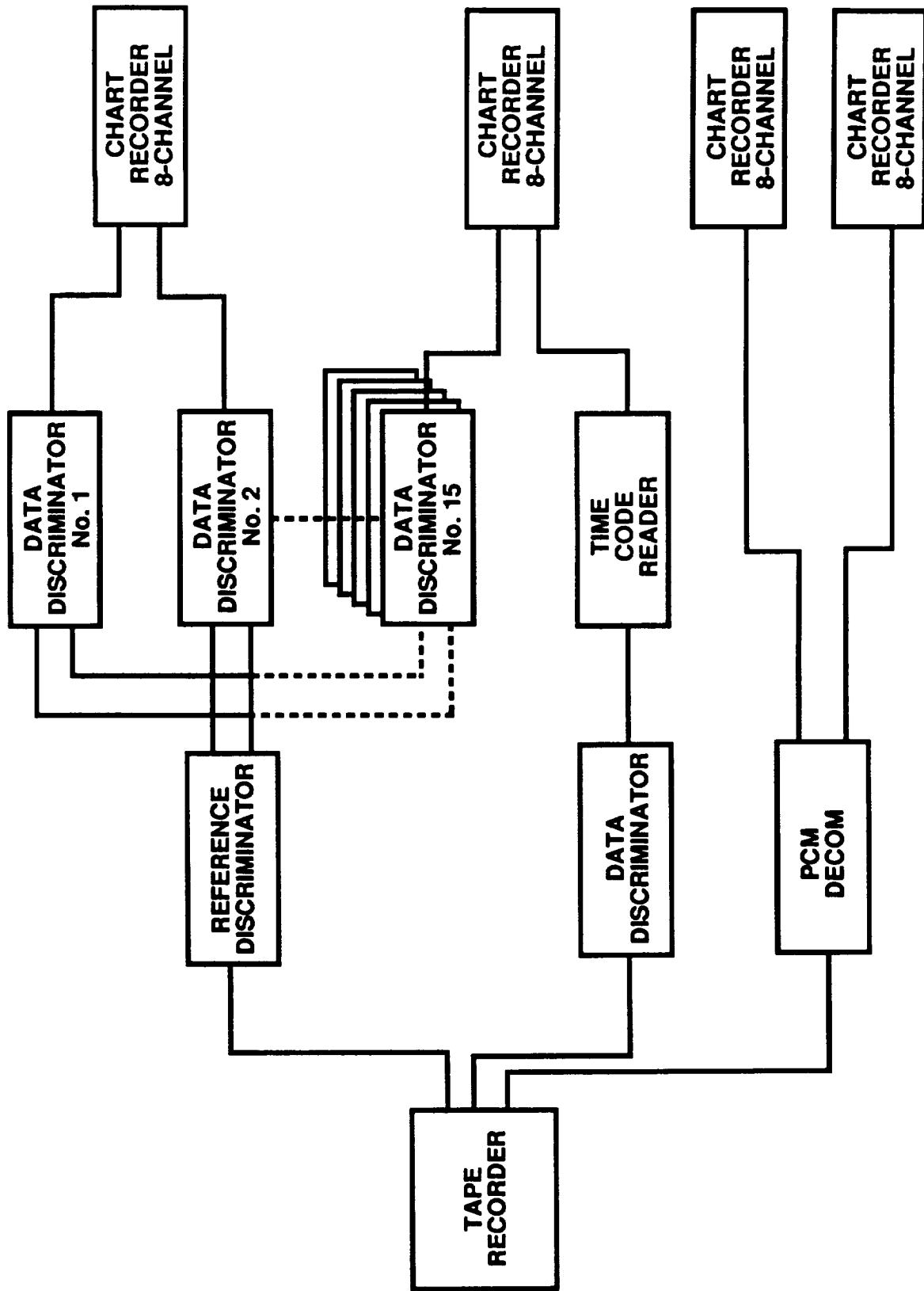
The laboratory's primary function is playing back of dubs of the  
Modular Auxiliary Data System flight tapes for identification by  
Measurement Discrepancies Records of flight hardware  
anomalies.

Strip chart records are made for all Modular Auxiliary Data  
System Measurement Stimulus Identifications on every flight and  
are used to support the post-flight Modular Auxiliary Data  
System and Development Flight Instrumentation Data review.  
The JSC Flight Data and Evaluation Office coordinates the data  
reviews and uses the agreeable Measurement Discrepancies  
Records for requesting Kennedy Space Center repair under  
Program Requirements Control Board direction.

The laboratory's secondary function is to verify the quality of the  
dubs of the flight tapes and support tests related to Modular  
Auxiliary Data System flight data or flight system.

DATA ACQUISITION: Data acquisition in the Modular Auxiliary  
Data System Laboratory is limited to the playback of analog  
instrumentation tapes (both pulse coded and frequency  
modulated modes) with output onto strip chart recorders.  
Oscilloscopes can be used for interrogating the characteristics  
of electrical signals on the instrumentation tapes.

**MODULAR AUXILIARY DATA SYSTEM BLOCK DIAGRAM**



## MODULAR AUXILIARY DATA SYSTEM LABORATORY VIEW



## **General Facility Specifications**

### **SOFTWARE DEVELOPMENT FACILITY**

**LOCATION:** Building 46

**POINT OF CONTACT:** Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

**STATUS:** Active

**YEAR BUILT:** 1986

**INITIAL COST:** Not available.

**REPLACEMENT COST:** Not available.

**USE:** The Software Development Facility supports the prime function of developing the software of the Orbiter Primary Avionics Software System and the Backup Flight System. The facility has recently acquired the function of performing the Flight Software Certification job on its computers located in Building 46. The deliverable built by programmers is an operational increment that is developed and tested in the Software Development Facility.

**DESCRIPTION:** The Software Development Facility consists of an Amdahl 5890-600E mainframe (configured as a 300E for facility support), Direct Access Storage Devices, printers, microfiche equipment tape drives, workstations and Flight Equipment Interface Devices. These interface devices allow testing and verification of the Shuttle operational software in a realistic multi-string data processing system environment. The

environment consists of the flight software being tested within the actual data processors and the Shuttle hardware and environment math models within the host. The interface devices allow the coupling of these asynchronous processors and provide the needed environment.

**STATUS:** A large percentage of the users of the Software Development Facility are remote to JSC, including Rockwell International, Downey, California, for the Backup Flight System, IBM, Houston, Texas, for the Primary Avionics Software System, and Intermetrics, Houston, for the compiler. User access to the facility is through the Center Information Network.

Facility operations support, sustaining engineering, and software maintenance are provided by Mission Operations Support Contractor through the Information Systems Directorate. The Flight Data Systems Division has the responsibility for hardware maintenance of the Amdahl equipment, with Mission Operations Support Contractor support. The remaining facility equipment is maintained by the Mission Operations Support Contractor.

The Software Development Facility is a four-way multiprocessor consisting of two tightly coupled dual processors. It operates in a partitioned mode (i.e., side A and side B), and with the Multiple Domain Facility product, each side supporting up to four domains. A domain configuration is a list of computing resources to be assigned to a domain when the domain is activated. These resources include storage, channels, and logical processors.

The Amdahl System 5890-600E has 384 megabytes of memory and ninety-six channels. The Software Development Facility resides on the A-side configuration and the rest of the system is allocated to the Ground System Software Production Facility and three test domains, i.e., the B-side. The processing complex consists of two mainframes, or a total of four central processing units (two units in each mainframe).

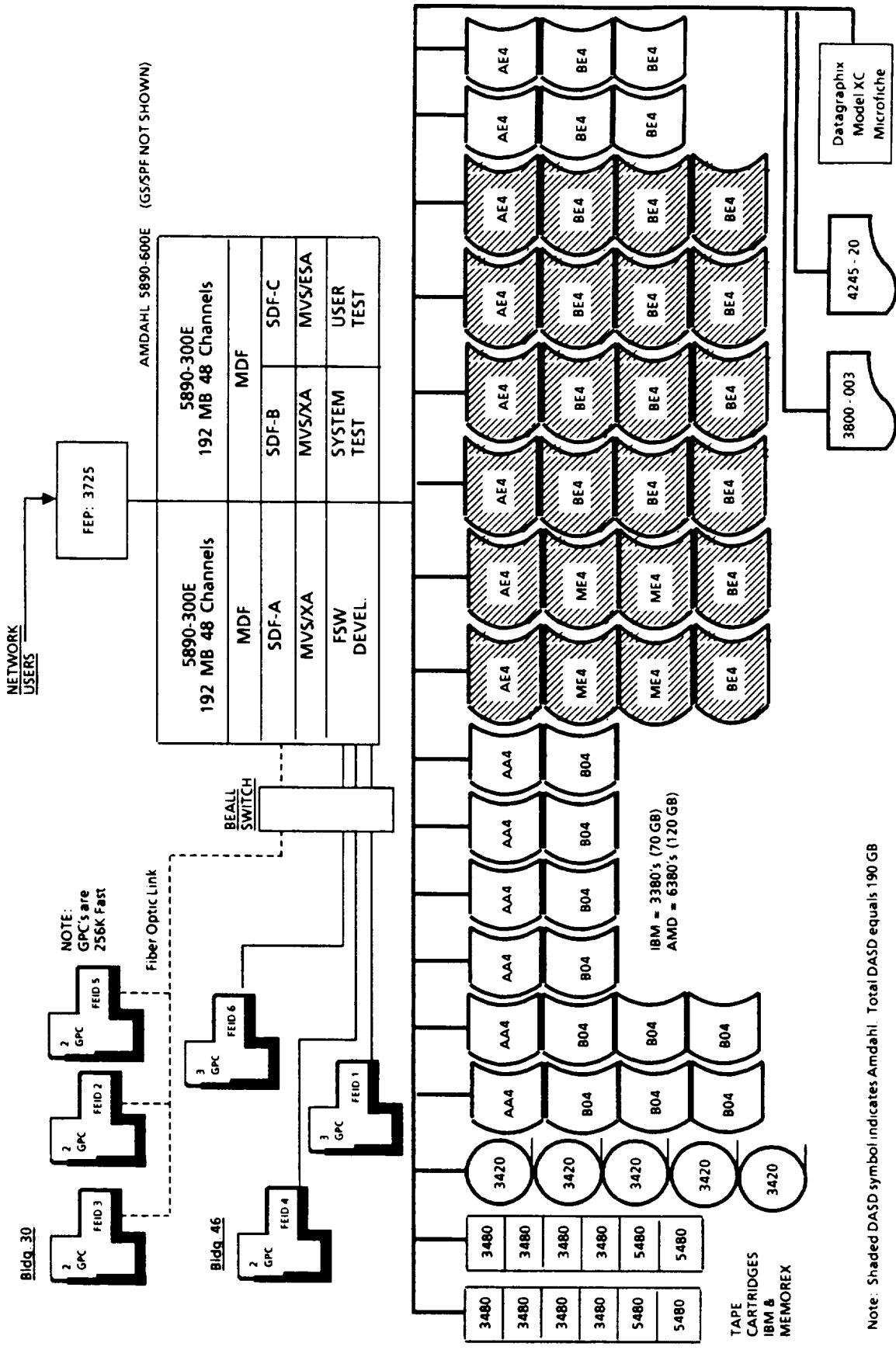
A Side Totals	B Side Totals
<b>Memory:</b> 192 megabytes	<b>Memory:</b> 192 megabytes
Cpus: 2	Cpus: 2
Channels: 48	Channels: 48
MIPS: 42	MIPS: 42
SDF-A	Test domain for SDF/MVS
Production domain	Test domain for SDF/ESA
MVS/XA Software	GS SPF/NM prod.
TSO	SPF/B
JES3	(ESA test)

The Software Development Facility and the Software Production Facility are required to maintain compatibility to allow software and tools developed in the Development Facility to be transported to the Production Facility for production. Synchronization of the facilities is accomplished via the Facility Synchronization Board.

Hardware and software upgrades were accomplished during FY 1990 and as a result have put the Software Development Facility in a favorable processing capacity condition. Hardware upgrades included an addition of forty gigabytes of Direct Access Storage Devices, a network upgrade at Rockwell, Downey, and Flight Equipment Interface Device upgrades. Software enhancements included the addition of an on-line documentation system and a relational data base.

DATA ACQUISITION: The Software Development Facility provides data acquisition via the media of direct access storage devices (hard disks), digital cartridge tapes, laser printers, mechanical line printers, a microfiche converter, workstations (digital computer terminals), optical disks, and digital computer tapes. A relational data base management system is utilized in the archiving process for data stored on all direct access storage devices.

## SOFTWARE DEVELOPMENT FACILITY HARDWARE CONFIGURATION



## General Facility Specifications MICROPROCESSOR LABORATORY

LOCATION: Building 16A, Room 2165

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1982

INITIAL COST: \$50k

REPLACEMENT COST: \$200k

USE: The Microprocessor Laboratory has the capability to support current and future manned spacecraft development of microprocessor-based experiment payloads and data management systems, breadboards, and flight components, as well as bench testing and maintenance of space vehicle data management equipment.

DESCRIPTION: This facility is a technical laboratory designed to support the development of microprocessor-based system breadboards and flight equipment. The primary intended use of the facility is hardware development. However, equipment and space are available for software development and general laboratory equipment repair.

The workspace in the laboratory is divided into three general areas. There are five general purpose workbenches where

most of the fabrication and assembly is performed. The workbenches contain drawers for storage of general laboratory supplies and technician tools, and there are a sufficient number of electrical outlets on each bench to provide the technician with power for tools, for equipment under development, and for any required test equipment.

The second workspace area contains six general purpose workstations to support hardware testing, the development of software, and other project activities. Hardware and software development tools are available to meet the requirements of various flight hardware applications.

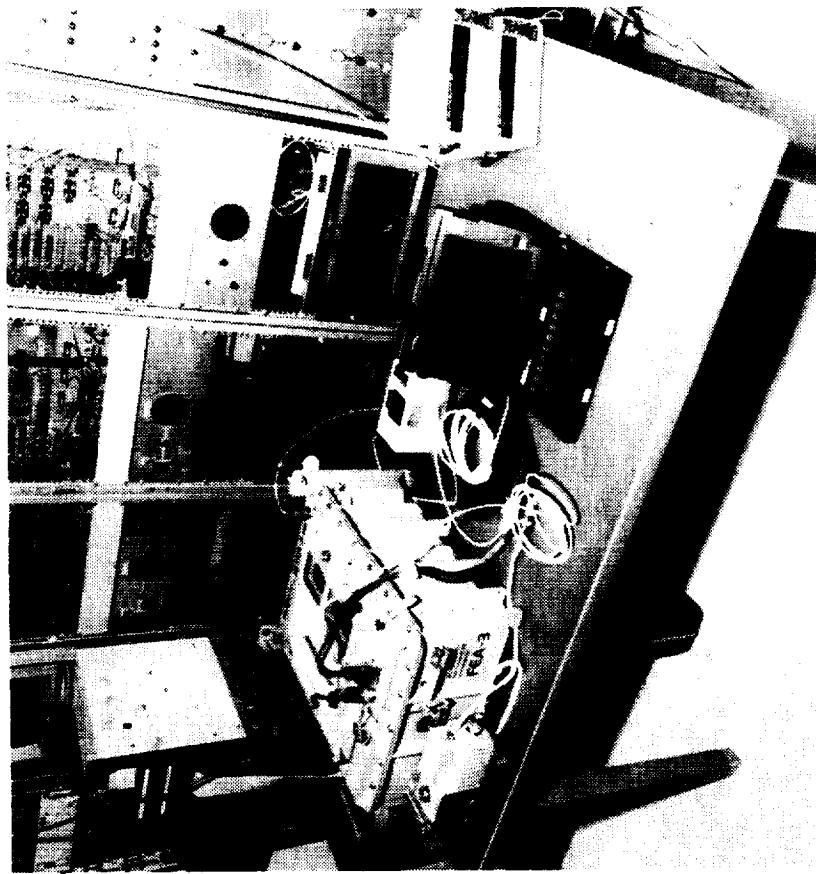
The third workspace area contains a clean bench for fabrication of flight-type equipment that requires special precaution in order to be kept free of contaminants. The clean bench has filtered air forced down onto an enclosed work surface that is protected in front by a plastic curtain.

In addition to the workspace, there are fourteen storage cabinets for laboratory supplies, tools, and parts storage. Five of the cabinets can be used to store Class I flight hardware. The entire laboratory is electrostatic discharge safe and all tools and supplies are handled by trained personnel in a manner to eliminate the risk of damage due to such discharges. A hanging file is provided for drawing storage.

DATA ACQUISITION: Data are acquired in the Microprocessor Laboratory primarily via digital computer terminals and archived on floppy and hard disks. Data are also acquired during the

equipment fabrication, test, and integration phases via digital and analog voltmeters, ammeters, and ohmmeters as well as oscilloscopes.

## PAYOUT AND GENERAL COMPUTER: UPGRADE PROCESS

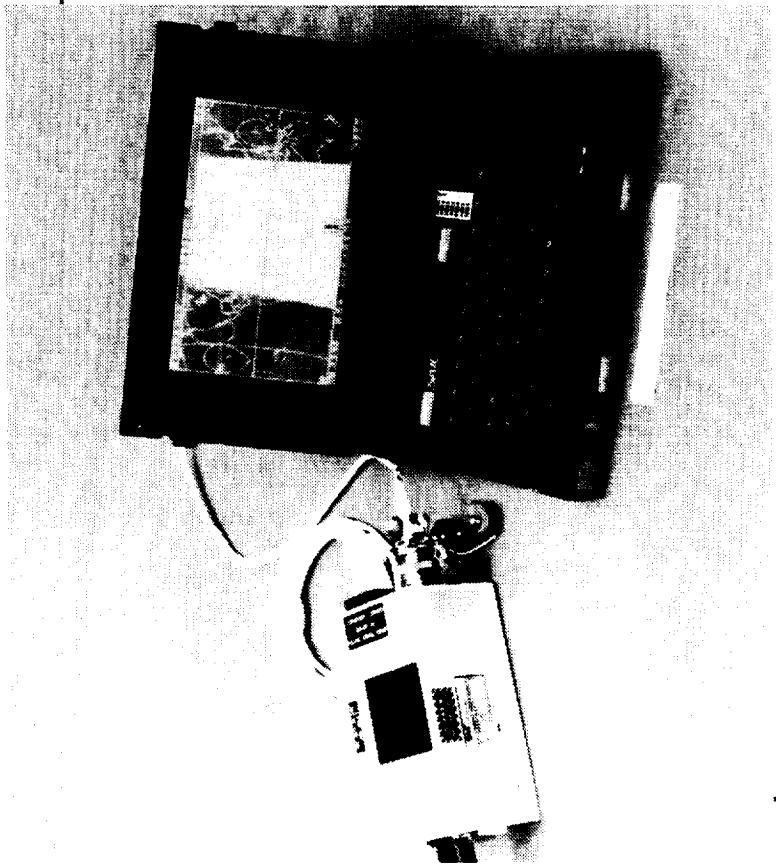


- PGSC - AN IBM COMPATIBLE GRIDCASE MODEL 1530 LAPTOP COMPUTER
- 80C386 12.5 MHz, 32-BIT PROCESSOR WITH 80387 COPROCESSOR
- GRID MS-DOS (MICROSOFT DISK OPERATING SYSTEM)
- AVAILABLE FOR SPACE SHUTTLE MISSIONS
- INTERFACES
  - RGB VIDEO PORT
  - FLOPPY DISK PORT
  - RS-232 PORT
  - PRINTER PORT
  - TWO RS-422 PORTS

## PAYOUT AND GENERAL SUPPORT COMPUTER

### IMPROVED PGSC

- CREW FAMILIAR WITH ELECTROLUMINESCENT (EL) DISPLAYS
- BETTER VIEWING FROM ALL ANGLES
- OPERATES INDEPENDENTLY OF ORBITER LIGHTING
- NO IMPACT TO CURRENT PGSC CAPABILITIES



590-52911

## General Facility Specifications

### FLIGHT TAPE RECORDER LABORATORY

LOCATION: Building 16A, Rooms 1032 and 1034

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$240k

REPLACEMENT COST: \$460k

USE: The Flight Tape Recorder Laboratory has the capabilities to support maintenance, engineering evaluations, calibration, problem analysis, and modification of flight tape recorders on current and follow-on programs.

DESCRIPTION: This facility provides spacecraft tape recorder maintenance support, engineering design evaluation and enhancement, magnetic tape analysis and certification, real-time mission support, and recorder interface engineering.

Support instruments include clean benches, bit error rate testers, recorder calibrators, flutter meters, a time interval measurement instrument, and general electronic and mechanical instruments.

Currently, this facility is being utilized to support the design testing of modifications to tape recorders to be used for orbiter experiments flight data dumps and for failure investigation and refurbishment of orbiter experiments recorders. Three twenty-eight-track orbiter experiments recorders are maintained by the laboratory.

To provide engineering support for the Shuttle tape recorders, an automated test station has been configured using a 386 personal computer and test instruments equipped with IEEE-488 computer interfaces. In addition, a data acquisition system consisting of analog to digital converters and digital input and output is used to interface the recorder's telemetry outputs to obtain analog and digital status information during testing. All software for this system was developed in-house and is continually updated to provide additional testing capabilities. Test data are automatically acquired and stored on computer for historical purposes and also for comparison with future testing for assessment of recorder performance over extended flight usage. This test station also provides the capability of performing recorder data quality evaluation in order to determine orbiter tape recorder changeout requirements. Special equipment provides the capability of performing recorder data quality evaluations in order to determine orbiter tape recorder changeout requirements. This equipment includes a time interval analyzer, a pulse code modulation data reduction system, a time code display, a special bit error

detector, a Compaq 386 computer, plotter, printer, disk drives, and both commercial and in-house-developed personal computer software. Several major test equipment items are on order to replace obsolete and uneconomical-to-repair items and to upgrade the capabilities of the laboratory. This equipment includes a high rate bit error tester, a twenty-eight-track tape certifier, a tape motion analyzer, and a tape recorder calibrator.

An automated test station is under development for the Payload High Rate Recorder. This recorder is a data recorder for experiments that will record image radar data on STS-60 and subsequent missions. The Payload High Rate Recorder utilizes

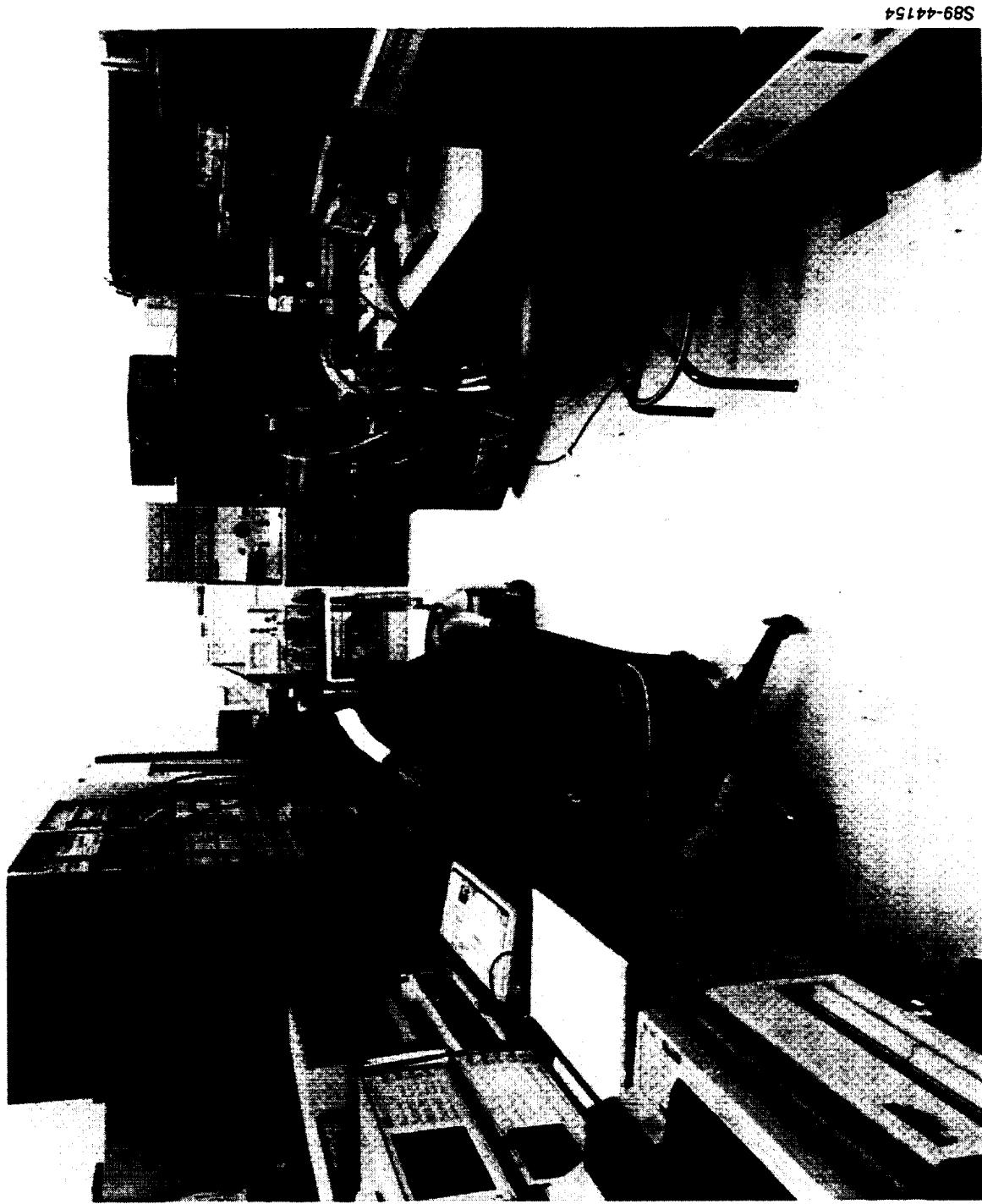
helical scan recording technology that allows it to record data at very high rates. To test the recorder, a special bit error rate tester was developed. Other equipment used for the Payload High Rate Recorder includes a 386 personal computer, spectrum analyzer, counter, and in-house developed personal computer software.

DATA ACQUISITION: Data acquisition in the Flight Tape

Recorder Laboratory is provided primarily by analog instrumentation tapes, oscilloscopes, floppy disks, hard disks, computer terminals, plotters, printers, digital and analog meters, and a special purpose bit error rate analyzing device.

**FLIGHT TAPE RECORDER LABORATORY**

**ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH**



## **General Facility Specifications**

### **INSTRUMENTATION LABORATORY**

**LOCATION:** Building 16A, Room 2008

**POINT OF CONTACT:** Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

**STATUS:** Active

**YEAR BUILT:** 1964

**INITIAL COST:** \$240K

**REPLACEMENT COST:** \$460K

**USE:** The Instrumentation Laboratory has the capabilities to support maintenance, engineering evaluations, calibration, failure analysis, modification, and design of flight hardware for instrumentation applications employing micro-machined smart sensors and advanced data recording technologies.

**DESCRIPTION:** This facility provides flight hardware support, engineering design, evaluation, calibration, failure analysis, and enhancement of instrumentation systems and high capacity mass storage devices.

Support instruments include the following: clean benches; a surface mount technology assemble and rework solder station; an air data testbed to control pressure, temperature strain, and phenomena associated with acceleration, vibration, and shock; various data acquisition systems; an assortment of highly

accurate, computer controlled electronic test equipment, including control software; micro-controller development and emulation systems; programmable integrated circuit support equipment; various transducers; a number of very dense mass storage devices including high-capacity hard disk drives, helical scan tape drives, optical and magneto-optical drives, as well as solid state memory modules; and general electronic and mechanical instruments.

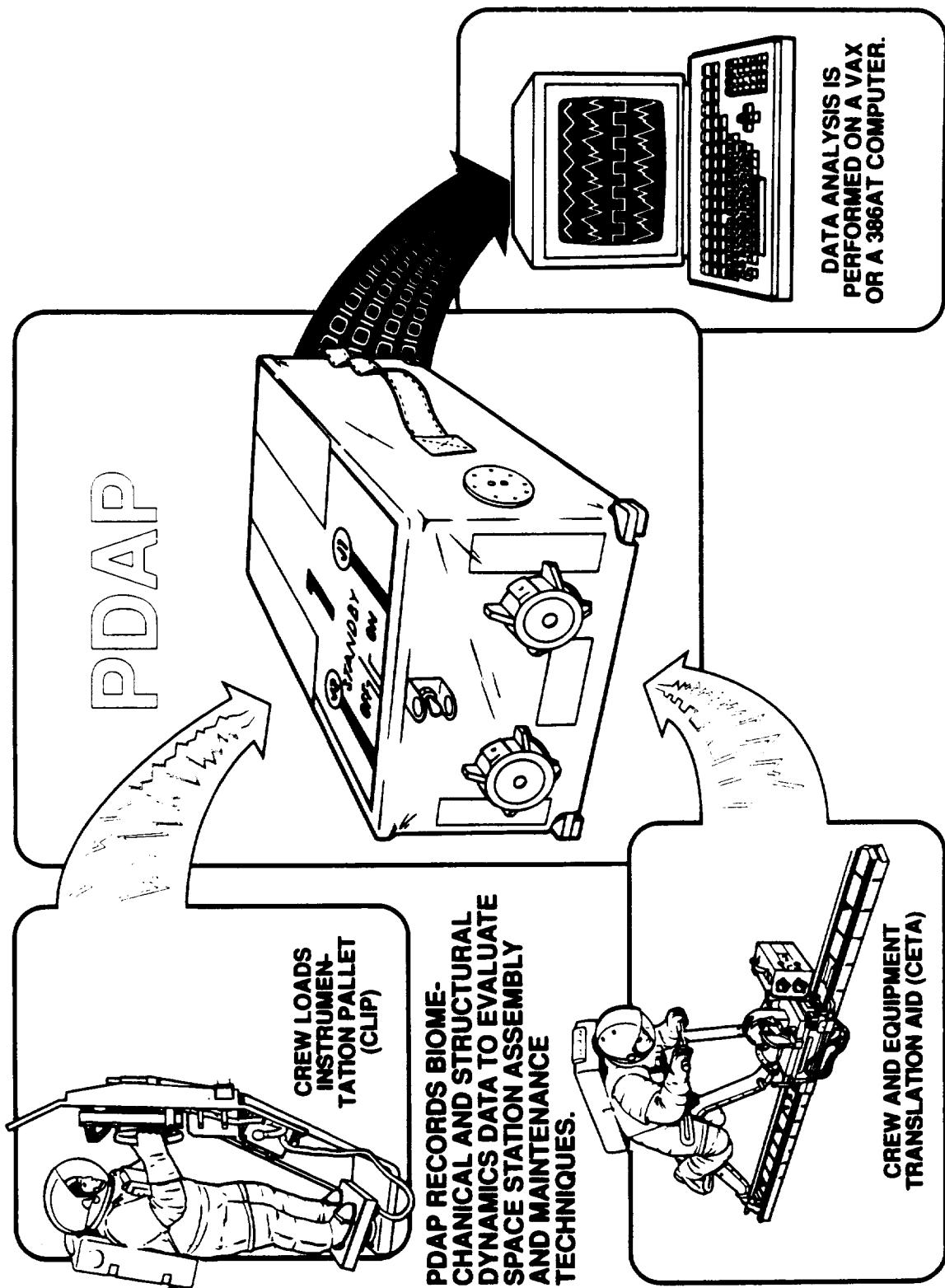
Currently this facility is being used to support the design, development, verification, and delivery of various flight hardware projects. The facility contains stand-alone instrumentation that includes a stand-alone acceleration measurement device, a stand-alone strain gage measurement device, and a portable data acquisition package.

Additional work includes the continued investigation of state-of-the-art mass storage technologies, advances in micro-machined smart sensors, progress in new sensor technology for the measurement of microgravity and other space-related measurements, as well as continuously monitoring the progress of the design, development, and fabrication of integrated circuits.

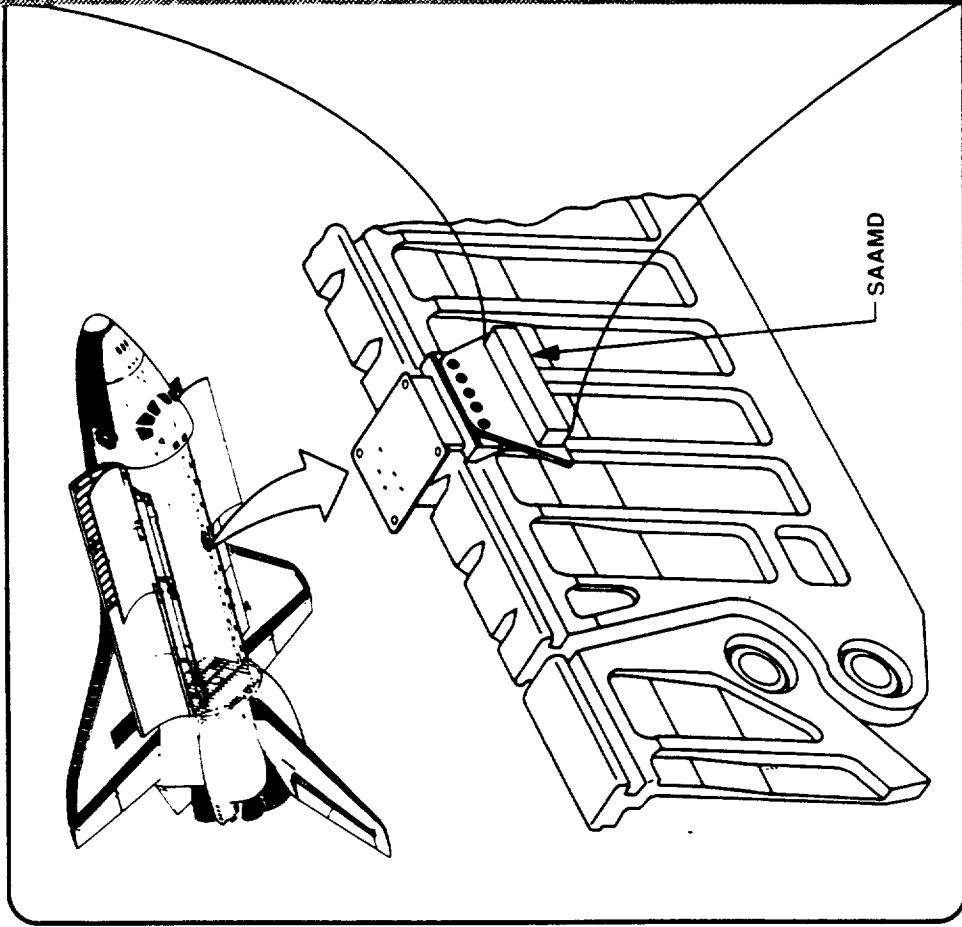
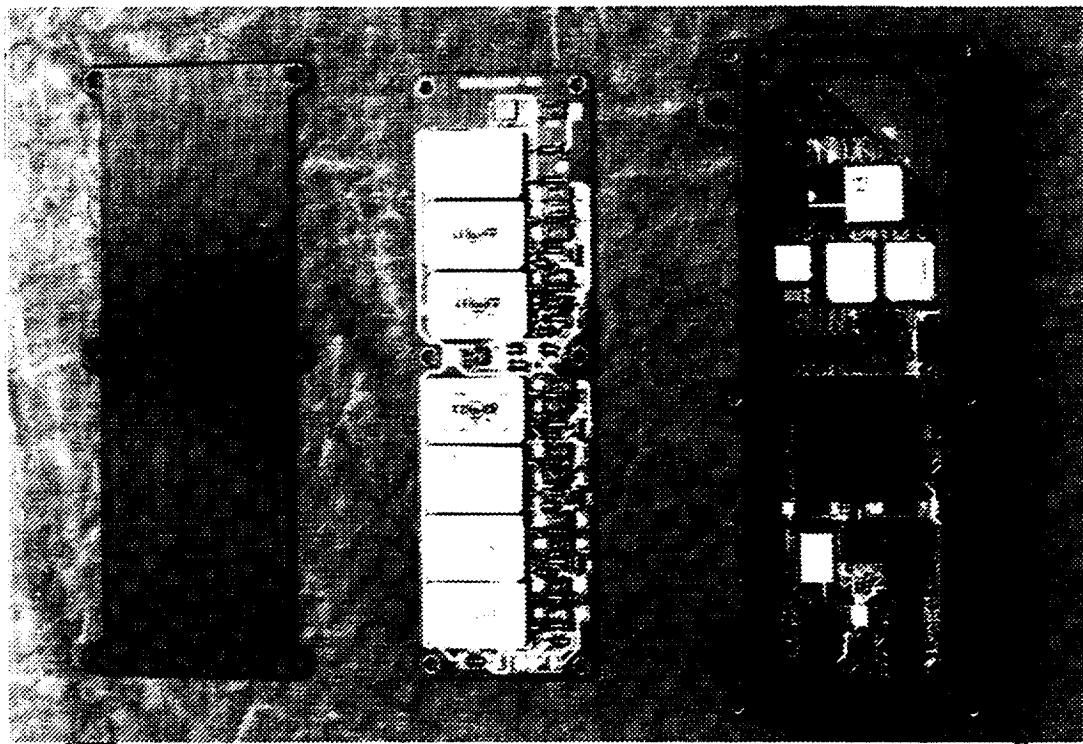
The Instrumentation Laboratory has the capabilities to design, develop, verify, and deliver flight hardware for instrumentation, control, and mass data storage systems. Other capabilities include the equipment to instrument various experiments, to test and evaluate transducers, systems, and storage devices.

**DATA ACQUISITION:** Data are acquired in the instrumentation laboratory primarily via digital computer terminals and archived on floppy and hard disks. Data are also acquired during the equipment test and integration exercises via digital and analog voltmeters, ammeters, and ohmmeters as well as oscilloscopes.

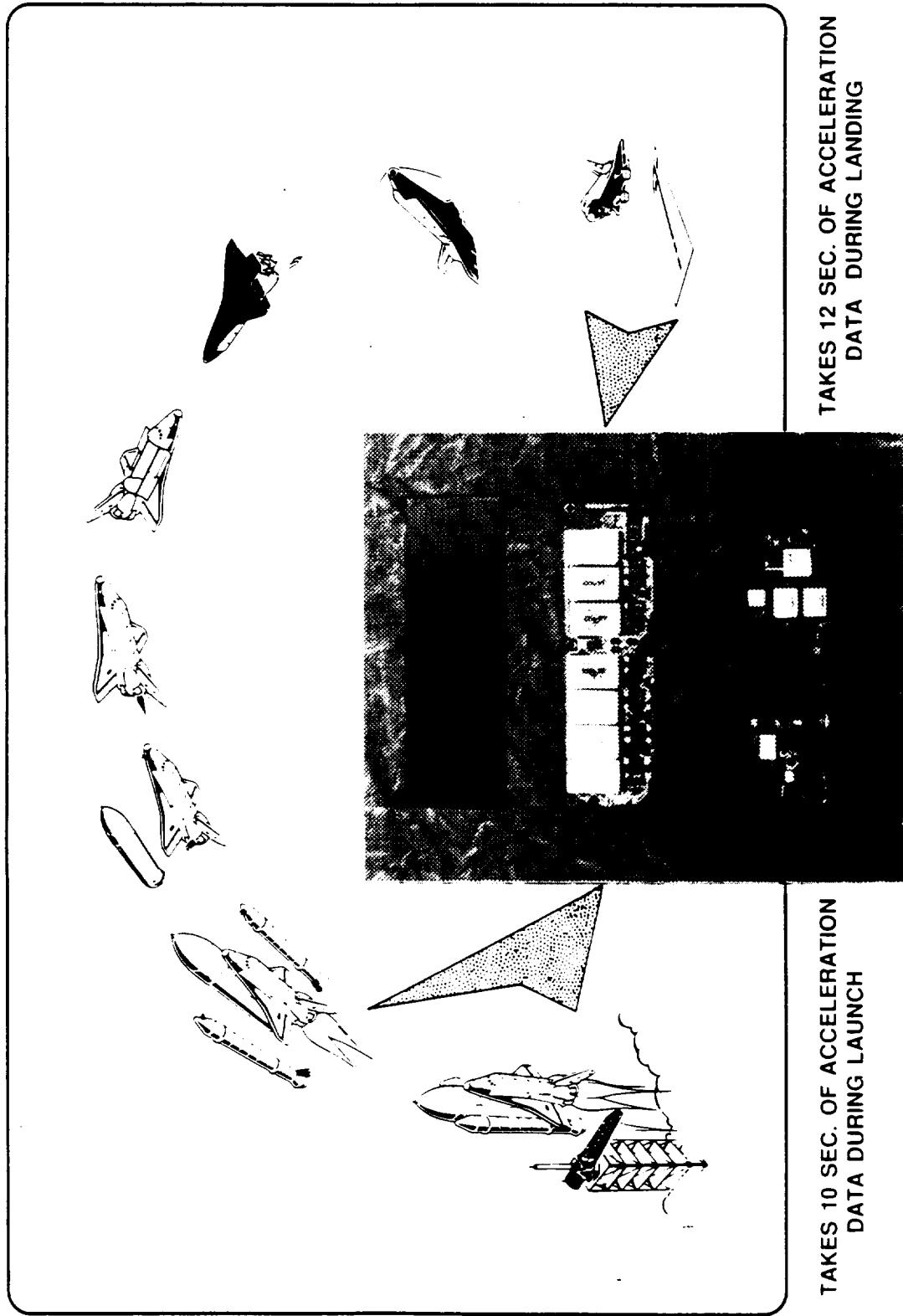
**PORTABLE DATA ACQUISITION PACKAGE**



## STAND-ALONE ACCELERATION MEASUREMENT DEVICE INSTALLATION ON BRIDGE FITTING IN PAYLOAD BAY



**ACQUISITION CYCLE OF STAND-ALONE ACCELERATION MEASUREMENT DEVICE  
LAUNCH AND LANDING SEQUENCE**



592-34909

**TAKES 12 SEC. OF ACCELERATION  
DATA DURING LANDING**

**TAKES 10 SEC. OF ACCELERATION  
DATA DURING LAUNCH**

## General Facility Specifications DISPLAYS AND CONTROLS LABORATORY

LOCATION: Building 16A, Room 2000

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1987

INITIAL COST: \$500k

REPLACEMENT COST: \$900k

USE: The Displays and Controls Laboratory of the Flight Data Systems Division has the capability of supporting the development and testing of displays and controls for various spacecraft programs, including Space Station Freedom, the Assured Crew Return Vehicle, the Shuttle orbiter, and other advanced programs. The laboratory also has the capability to perform hardware, software, and implementation studies for various spacecraft systems.

DESCRIPTION: The Displays and Controls Laboratory is located in Building 16A. The laboratory has developed the capability to support testing associated with man-in-the-loop operations of real-time display and control activities. These operations are accomplished via prototyped Space Station and Shuttle orbiter simulation data values generated from various

computers networked together for development and performance evaluation.

There are four distinct areas within the Displays and Controls Laboratory:

- A MicroVAX III Plus Computer System to support all testbed activities
- A Shuttle Orbiter Aft Station Testbed for supporting display and control activities for both the orbiter and Space Station Freedom
- A Space Station Multipurpose Application Console Testbed that is interfaced to other laboratory computer systems and that provides Space Station prototyping
- A Displays and Controls Component Testbed that provides an area to develop and evaluate low-level electronic components

The Digital Equipment Corporation MicroVAX III Plus Computer System is interfaced to the laboratory Ethernet Local Area Network and provides the centralized support for data display, operations control, and limited data analysis. This system supports Digital Equipment Corporation's DECnet as well as Transmission Control Protocol and Internet Protocol for networking operations. This dual capability allows the system to interface with VAX computers within JSC and with other computer systems located in the laboratory.

The Orbiter Aft Station was designed to support display and control operations originating from the Shuttle. This testbed

**supports the use of several hand controllers to perform various robotic activities. The system is supported by an out-the-window simulation scene and various display and control devices mounted in the aft station. The testbed is used to support both Shuttle and Space Station oriented activities.**

The **Space Station Multipurpose Applications Console Testbed** provides the means for prototyping Space Station oriented display and control techniques. The testbed is highlighted by a prototype workstation console that parallels the Space Station design. The system supports real-time, man-in-the-loop activities associated with Space Station operations. The testbed includes a simulated scene from a display processor and video from cameras located in the laboratory. It also includes the hardware and software resources necessary to control the performance of operations existing in that environment.

The Displays and Controls Component Testbed provides a facility for low level electronic design and evaluation. This activity emphasizes actions associated with the display of data

and status information and control of the user environment. Research items include flat panel evaluation, evaluation of programmable display pushbuttons, evaluation of a voice recognition system, customer processor application development, and Small Business Innovative Research projects. A limited amount of hand controller evaluation components may be evaluated independently or integrated with other laboratory testbeds.

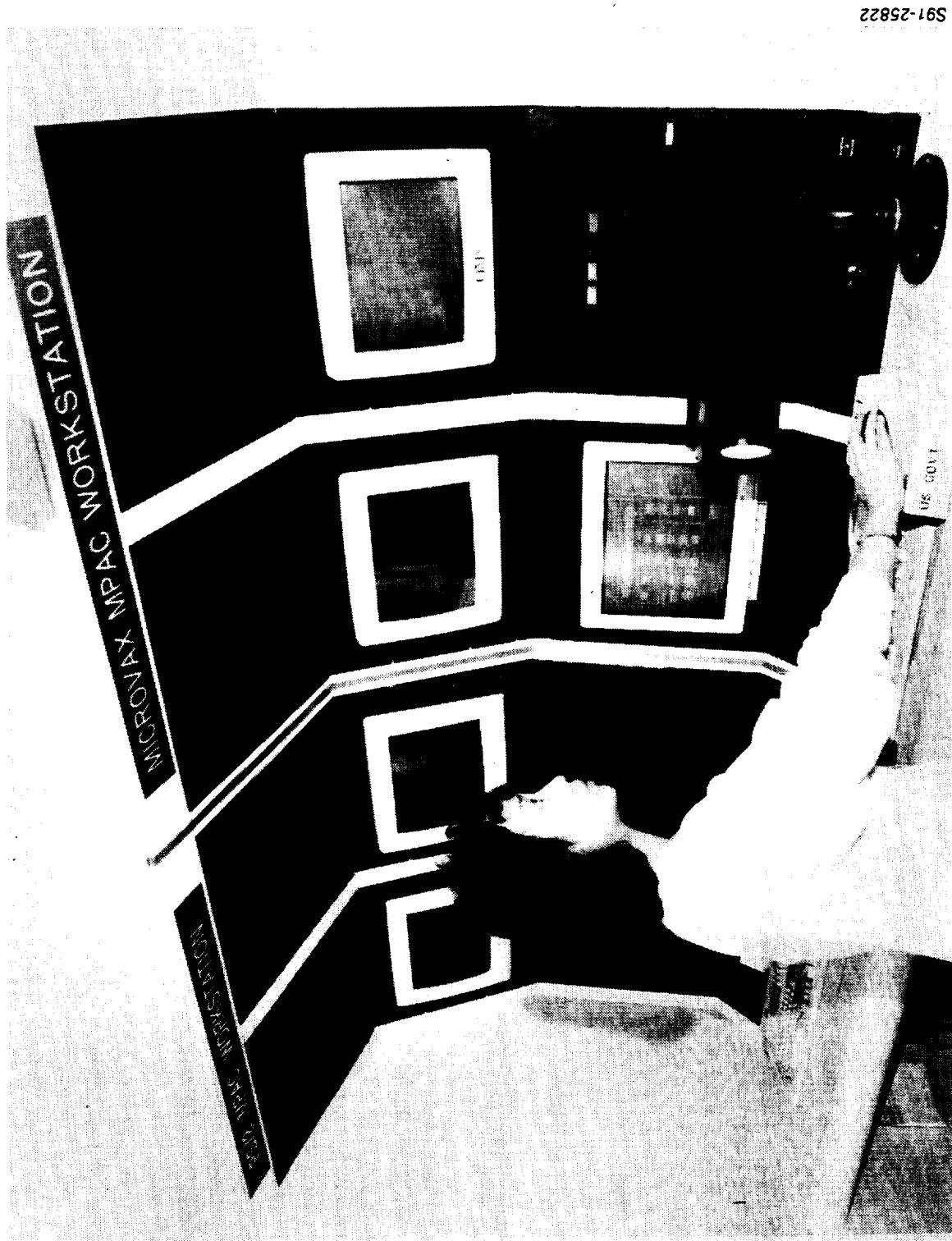
**DATA ACQUISITION:** The Displays and Controls Laboratory data acquisition functions are provided via analog and digital meters, cathode ray tube displays, television scene presentations, and several prototypical Shuttle and Space Station display and control devices (lighted push-buttons, annunciators, hand controllers, etc.). Data are presented via digital terminals, as well as analog and digital meters and annunciators. Data are archived on several media including digital cartridge tapes, floppy disks, hard disks, hard copies of terminal displays, and computer printouts.

**ORBITER AFT FLIGHT DECK WORKSTATION**



S91-25821

## DISPLAYS AND CONTROLS LABORATORY



## REAL-TIME SYSTEMS ENGINEERING LABORATORY

### General Facility Specifications

LOCATION: Building 16, Room 290

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1990

INITIAL COST: Not available.

REPLACEMENT COST: Not available.

USE: The Real-Time Systems Engineering Laboratory is a research laboratory within the Flight Data Systems Division. The laboratory's purpose is to develop a generic open data systems architecture that will provide the backbone for future space data systems. Through the use of computer aided Systems Engineering tools, modeling, simulation, and proof-of-concept prototype construction, the laboratory supports development of architecture standards and requirements for future data systems. In addition to the division's projects, the Real-Time Systems Engineering Laboratory supports projects for Software Engineering Institute, MITRE Corporation, and the United States Air Force's Rome Air Development Center.

DESCRIPTION: The Real-Time Systems Engineering Laboratory consists of a number of personal computers and

workstations. These are used to analyze and develop space systems, network standards, and interface technologies. The laboratory is undergoing enhancement with additional tools to perform computer-aided Systems Engineering functions on existing workstations. The computers and workstations are connected to a local Ethernet that is tied to the JSC Engineering and Science computer network.

The laboratory is currently equipped with two Apollo workstations running the Teamwork, Matrix-X, Alsys, Space Station Software Support Environment (SSE), SSE development and Motif and X-Windows tools; a VAXstation 3200 and a MicroVAX II running Digital Equipment Corporation Ada, Digital Equipment Corporation C, and 386 Assembler tools; PS/2 Model 80s running X-Windows, C compilers, Alsys Ada, and SSE Development tools; a Macintosh II running X-Windows, Interleaf, Meridian Ada, and SSE Development tools; an Intel 386/16 Multibus II development station; several terminals and laser printers. A SPARC Station I clone and a 486 personal computer are being acquired with the Statemate Computer-Aided Systems Engineering and Simulation and other tools.

Currently, many projects are being actively investigated in the Real-Time Systems Engineering Laboratory facility. These include efforts addressing network and system operation, supporting Integrated Test and Verification Environment, evaluating software life cycle elements, working with Ada, and performing requirements and system analyses.

An analysis of Space Generic Avionics is being performed to establish an open, standard flight data systems architecture using computer-aided Systems Engineering tools. Both static and dynamic models of the architecture will be created. This effort will also identify standard hardware and software components, and map the software architecture onto the hardware components. The basis of this architecture will be the Space Station architecture, modified as needed to improve its applicability to future space programs. The development process for this effort will be used to establish an "as-built" version of the methodologies used as a basis for a standard design analysis methodology.

Support investigations by the Integrated Test and Verification Environment include investigations of the Integrated Test and Verification Environment Executive using Ada, modeling focusing on Integrated Test and Verification Environment design integration issues, and definition of templates to generate Ada code for the Integrated Test and Verification Environment. The MITRE Corporation is investigating Matrix-X tool use in evaluating simulations, used in conjunction with the Integrated Test and Verification Environment and addressing code maintenance issues.

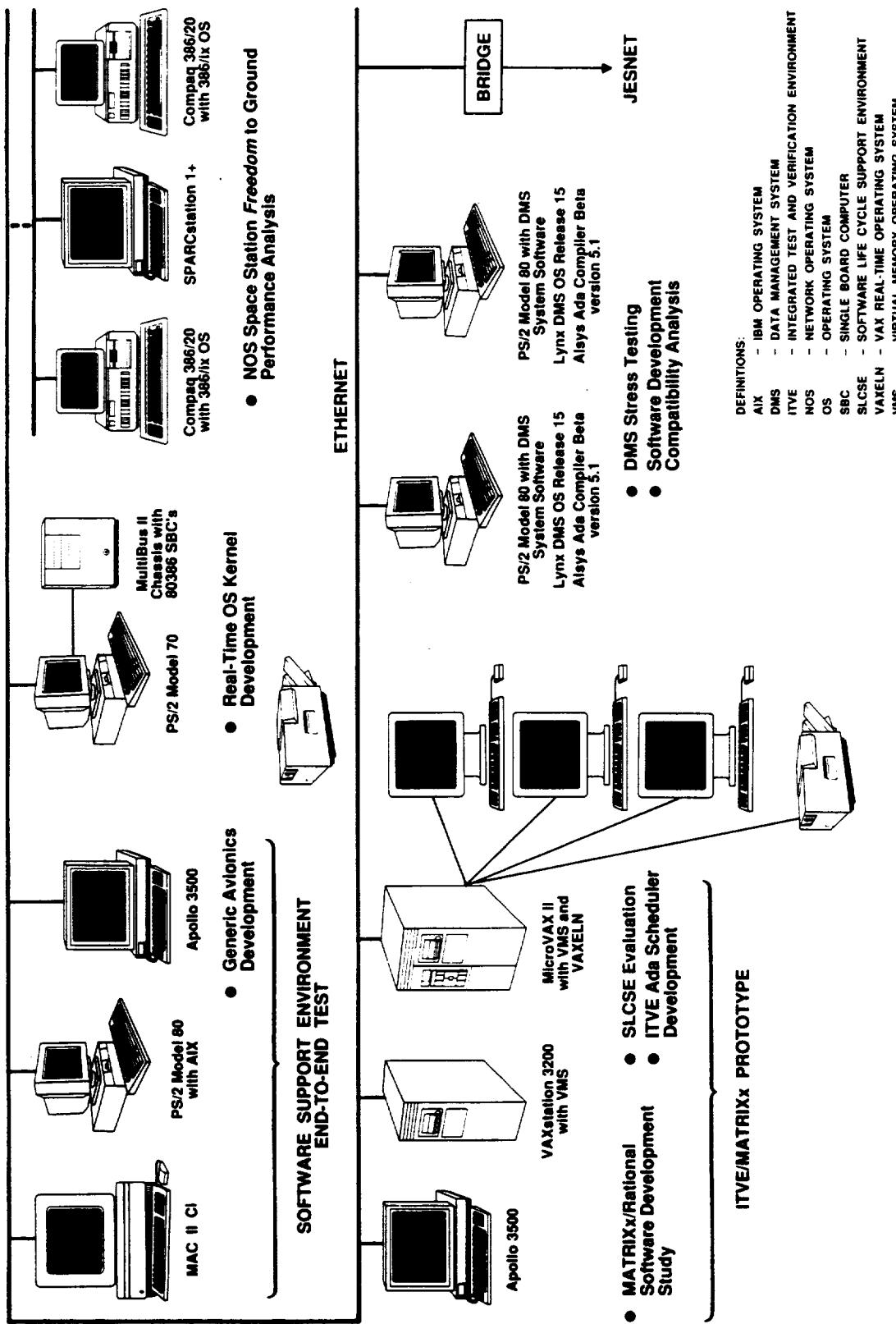
The SSE support investigations include development of end-to-end operations test capabilities and demonstrations of end-to-end test concepts.

Operating system investigations under way in the Real-Time Systems Engineering Laboratory include efforts to implement new algorithms for real-time operating system kernel prototypes, network and operating systems concepts definition and demonstration, and device driver development.

The Software Engineering Institute has identified a set of conditions in UNIX-like operating systems that cause kernel, input and output, and data transmission functions, operating on behalf of lower priority tasks to prevent preemption by tasks of higher priority. Their benchmarks, the Realtime Hartstones, precisely measure the effects of these unintended priority inversions and assist in quantifying the effects of these inversions on the real-time task set. The Real-Time Systems Engineering Laboratory has a set of these benchmarks and has exercised the Lynx Operating System against them to determine from analysis of the Lynx structure what additional priority management weaknesses may exist within the Lynx kernel.

DATA ACQUISITION: Data are acquired in the Real-Time Systems Engineering Laboratory primarily on floppy disks, hard disks, and computer terminals. Printouts of data are also provided.

## REAL-TIME SYSTEMS ENGINEERING LABORATORY BLOCK DIAGRAM



## **General Facility Specifications**

### **SPACE STATION 1553 LOCAL BUS TEST BENCH**

**LOCATION:** Building 16A, Room 1026

**POINT OF CONTACT:** Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

**STATUS:** Active

**YEAR BUILT:** 1990

**INITIAL COST:** \$200k

**REPLACEMENT COST:** \$200k

**USE:** Space Station 1553 Local Bus Test Bench activities have focused on the development and application of hardware testing and simulation capabilities. Computer models of data bus flight cables, bus couplers, connectors, buffers, and other electrical components are developed and tested using realistic data patterns in a specific Space Station bus configuration. Hardware was built and integrated to perform the same functions of validating the software models and providing additional testing capabilities.

**DESCRIPTION:** The 1553 Local Bus Test Bench consists of two sets of equipment used to test Space Station bus concepts.

A Mentor Graphics workstation consisting of an Apollo computer, computer-aided design software, and a plotter is used to develop software models of specific bus components, including cables, couplers, connectors, data repeaters, and data buffers. These components are then connected together (in software) in a specific configuration and tested. The test results are used by the Space Station community to design the bus architecture.

The second set of equipment includes a 1553 bus tester (data generator and analyzer), rack-mounted couplers, flight cables, and test equipment. The cables, couplers, and test equipment can be connected in a specific configuration and tested. The test results are provided to the Space Station community designing the bus architecture.

The Guidance, Navigation, and Control bus architecture and the Mobile Support Servicing and Remote Manipulator Systems bus architecture were studied with both hardware and software systems.

**DATA ACQUISITION:** The 1553 Local Bus Test Bench provides data acquisition via floppy disks, hard disks, computer terminals, and oscilloscopes. A data bus traffic analyzer is also used for data acquisition in the laboratory.

**1553 LOCAL BUS TEST BENCH**



## **General Facility Specifications**

### **TIME GENERATION SYSTEM TESTBED**

LOCATION: Building 16A, Room 1026

POINT OF CONTACT: Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

STATUS: Active

YEAR BUILT: 1990

INITIAL COST: \$180K

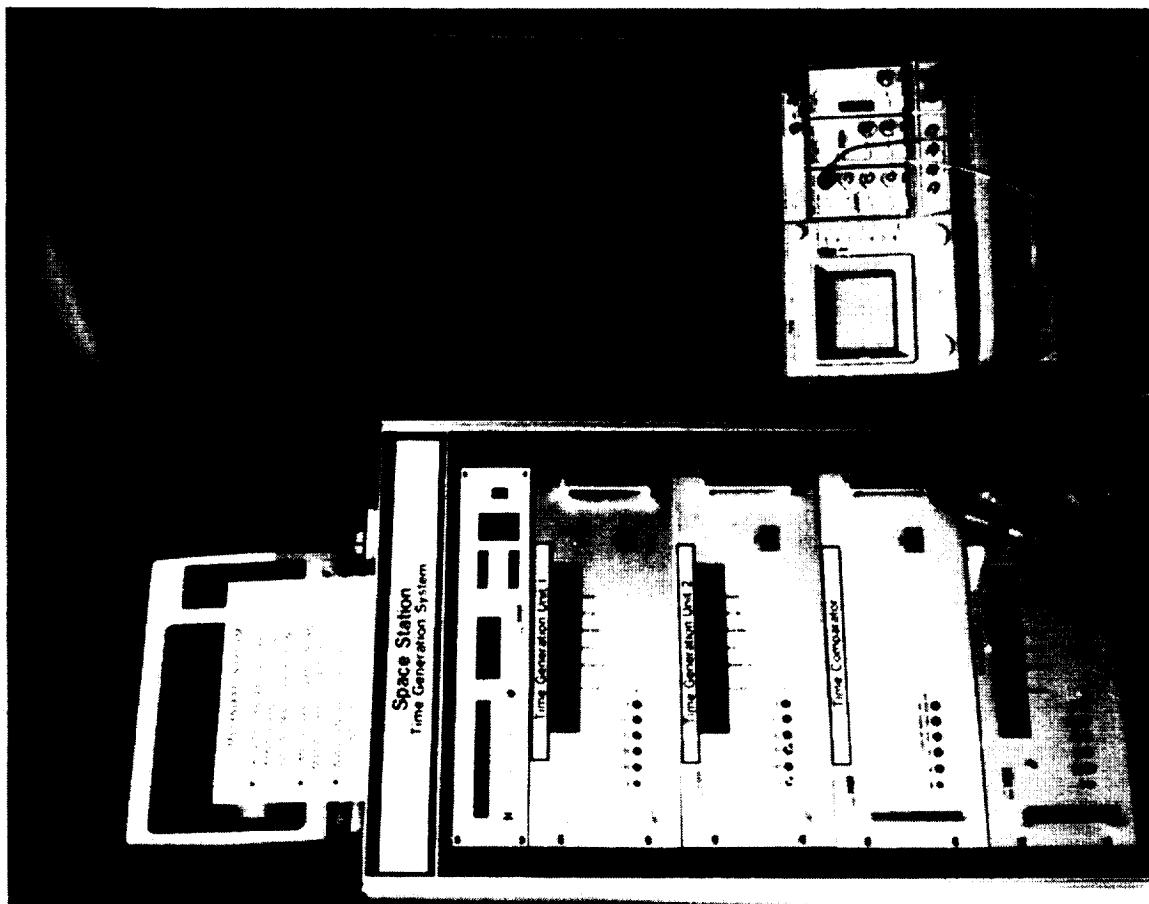
REPLACEMENT COST: \$180K

USE: Space Station Time Generation and Distribution System  
Testbed activities have focused on the development of a  
prototype redundant time source and fiber-optic distribution  
system to Space Station Freedom standards. Integration with  
the Data Management System Kit was also completed.

DESCRIPTION: The Time Generation System consists of rack-  
mount hardware, software, and several data busses used for  
control and time distribution. The system is connected to a  
radio-frequency standard time signal for synchronization. Two  
time generators are used in parallel for redundancy. A time  
comparator processor monitors the generators to ensure  
accuracy. Time distribution is achieved using a fiber-optic data  
bus, a 1553 bus, or an IEEE-488 interface. Control data are  
exchanged via an RS-232 interface or the 1553 bus. Software to  
distribute time and control the components is embedded in the  
hardware.

DATA ACQUISITION: Data are acquired in the Time Generation  
System Testbed on floppy disks, hard disks, computer  
terminals, and seven segment liquid crystal digital displays.

## TIME GENERATION SYSTEM TESTBED



## **General Facility Specifications**

### **MULTIPLEXER/DEMULITPLEXER AND ORBITER DATA BUS TEST LABORATORY**

**LOCATION:** Building 16, Room 290

**POINT OF CONTACT:** Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

**STATUS:** Active

**YEAR BUILT:** 1989

**INITIAL COST:**

**REPLACEMENT COST:**

**USE:** The Multiplexer/Demultiplexer and Orbiter Data Bus Test Laboratory is used by personnel from the Flight Data Systems Division and Rockwell, Downey, California, for testing the orbiter multiplexers, demultiplexers, and data buses.

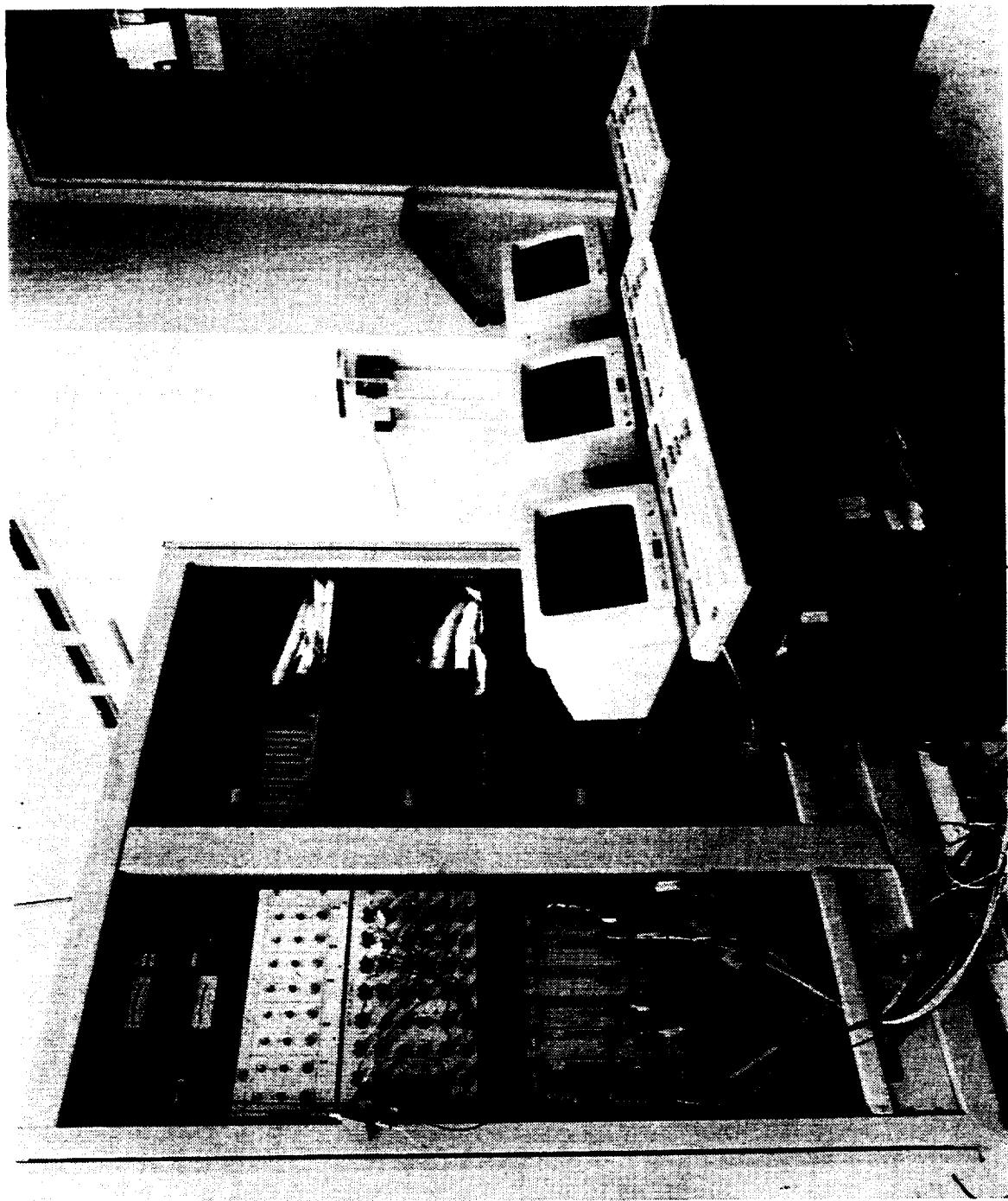
**DESCRIPTION:** The Multiplexer-Demultiplexer Test Set and the Data Bus Test Set are located in the laboratory. The Multiplexer-Demultiplexer Test Set consists of hardware that is capable of issuing commands to multiplexers and demultiplexers. The hardware also provides the necessary loading to test the input of both and output signal characteristics while also providing power to the unit under test. The facility has

also been used to replace shop replaceable units in nonflight multiplexers and demultiplexers. The laboratory also consists of a breadboard that is used to examine the internal operations of multiplexers and demultiplexers, investigate field reported failures, and evaluate design changes to the orbiter line replaceable units.

The Data Bus Test Set is used to test and evaluate all aspects of the orbiter data bus system. The laboratory hardware has the capability to test the data bus interface units known as multiplexer interface adapters by providing access to all of its interfacing signals. Numerous tests have been performed in the laboratory to determine the compatibility between old and new multiplexer interface adapter designs. The test fixture can also be configured to simulate any of the orbiter's twenty-four data bus word error rates, bus performance margins, and effects of proposed changes to any of the buses.

**DATA ACQUISITION:** Data are acquired in the Multiplexer/Demultiplexer/Data Bus Test Laboratory via digital and analog voltmeters, ammeters, and ohmmeters plus oscilloscopes and displayed on digital computer terminals. Data are archived in the laboratory on digital computer floppy disks and hard disks.

**MULTIPLEXER/DEMULTIPLEXER/ORBITER DATA BUS TEST FIXTURE**



## **General Facility Specifications**

### **COMPUTING FACILITY**

**LOCATION:** Building 16

**POINT OF CONTACT:** Chief, Flight Data Systems Division,  
Code EK, (713) 483-2401

**STATUS:** Active

**YEAR BUILT:** 1988

**INITIAL COST:** \$2,000k

**REPLACEMENT COST:** \$1,500k

**USE:** The Computing Facility of the Flight Data Systems Division is shared with the Navigation, Control, and Aeronautic Division. The primary use is for office automation and general purpose computation applications.

**DESCRIPTION:** The primary system within the division facility consists of a Digital Equipment Corporation VAX 11-785 computer and a VAX 8810 computer clustered together in a homogeneous configuration. The VAX cluster configuration provides redundant operation and minimizes impact because of system downtime inaccessibility.

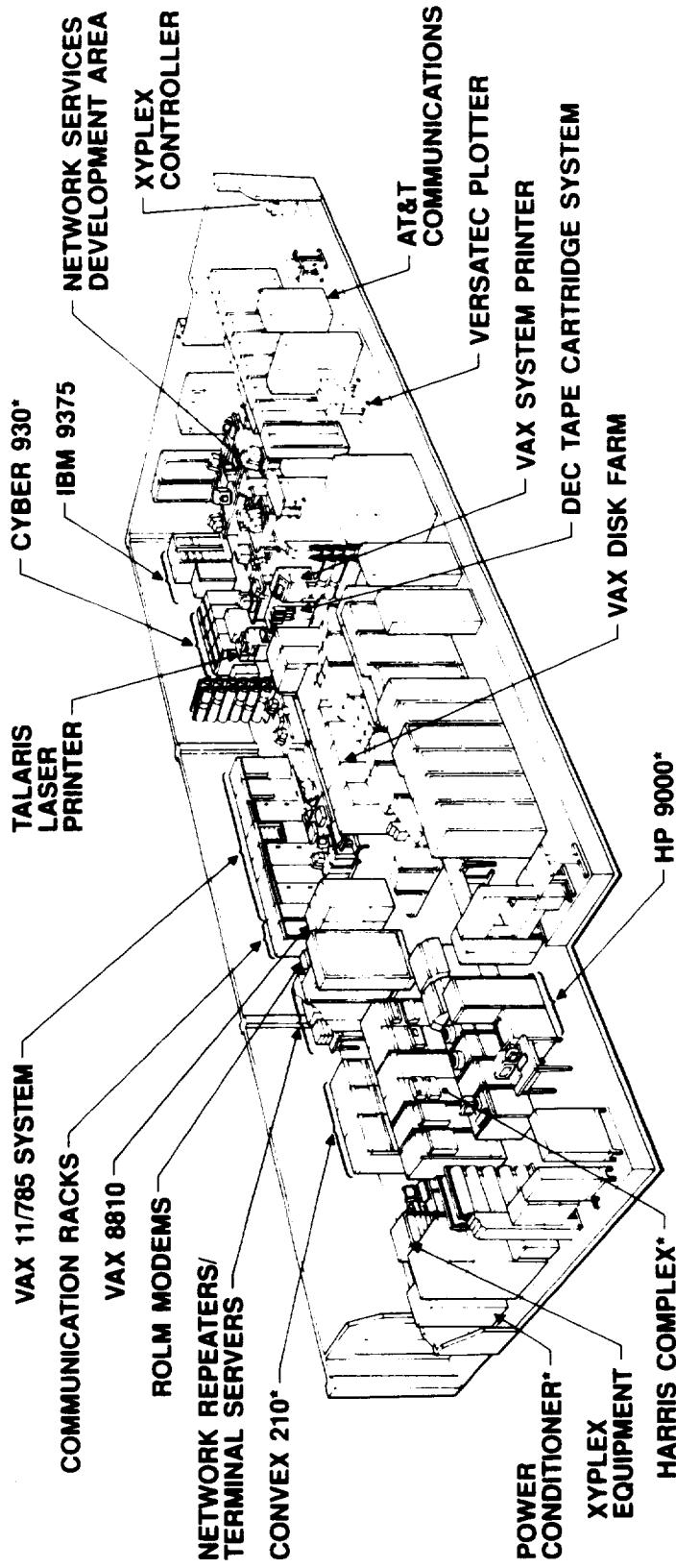
During the previous operating year, the associated peripherals were augmented with two tape transport systems (TA90 and TU78), a 9.6 gigabyte disk storage array (SA600), and a high speed printer (LP27). Access to this system is provided to civil

service and support personnel of both divisions and to the Simulation Systems Branch of the Systems Engineering Division. This system is connected to a building-wide thick and thin wire Ethernet network circuit. The network allows all offices and laboratories within the support divisions to access the system and provides a communication path to other directorate, center, and agency computational facilities. The facility was extensively modified between December 1989 and March 1990 to meet standards requiring the area to be designated as a Class 1 computer facility.

An extension of the computer facility is an external, divided room. The Flight Data Systems Division has two primary computer-aided design software packages, Futurenet and AutoCAD, installed on a personal computer. The software is used by a full time operator to produce electrical schematics and mechanical drawings for flight hardware and ground support equipment. Finished drawings in NASA format can be plotted on either of two A through E sized plotters, on vellum, for release through the drawing control system. In addition, there are other software packages available on individual personal computers for use by engineers in producing preliminary sketches.

**DATA ACQUISITION:** Data acquired in the Computing Facility are presented to the user community on computer terminals, X-Y plotters, laser printers, and line printers. Data are archived on direct access storage disks, digital tapes, cartridge tapes, floppy disks, and printer listings.

## FLIGHT DATA SYSTEM DIVISION COMPUTING FACILITY



## PRIMARY ACTIVITIES

- ENGINEERING COMPUTING
- NETWORKING
- MANAGEMENT INFORMATION AND DATA

## Chapter 5

### PROPULSION AND POWER DIVISION (EP)

#### **Contents**

<b>FACILITY</b>	<b>PAGE</b>	manufacture, and checkout activities, both in-house and through contractors.
Electrical Power Systems Laboratory .....	5-2	The division supplies pyrotechnic devices and explosives (in the form of Government-furnished equipment) to requesting programs and furnishes technical management for these pyrotechnic devices. It supplies batteries and cells (as Government-furnished equipment) to requesting programs and furnishes technical management for battery power supplies.
Thermochemical Test Area .....	5-4	
Thermal Vacuum Test Facility .....	5-6	
Pyrotechnics Test Facility .....	5-10	
Propulsion Test Facility .....	5-14	
Power Systems Test Facility .....	5-19	
Fluid Systems Test Facility .....	5-24	Propulsion and Power supports payload engineering and verifies compliance with safety requirements in the areas of propulsion, pyrotechnics, power, and fluid systems.

#### **Overview**

The Propulsion and Power Division is responsible for defining requirements for analyzing, designing, developing, testing, evaluating, and verifying current and advanced components and systems for spacecraft propulsion, pyrotechnics, cryogenics, electrical power generation, electrical power distribution and control subsystems, turbine power, fluid power subsystems, and on-orbit fluid servicing.

Propulsion and Power supports program and project offices by providing technical management within the functional areas of responsibility. It further supports advanced projects and future programs by providing technical management of requirements definition, analysis, design, development, test, evaluation,

The division operates and maintains Thermochemical Test Area facilities for a variety of test purposes: testing propulsion, pyrotechnics, power generation, and other hardware; testing electrical power systems and components and electrical wiring (the latter in the Electrical Power Systems Laboratory). The division provides technical and management support to NASA for on-orbit fluid servicing for earth-storable and cryogenic propellants and pressurant gases. It also provides technical advisement concerning explosion hazards analysis activities required at JSC.

## General Facility Specifications

### ELECTRICAL POWER SYSTEMS LABORATORY

LOCATION: Building 16, Rooms 147 and 171

POINT OF CONTACT: Chief, Propulsion and Power Division,  
Code EP, (713) 483-3995

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$40k

REPLACEMENT COST: \$1,600k

USE: The Electrical Power Systems Laboratory has a fully-equipped, high-fidelity breadboard of the Shuttle electrical power distribution and control subsystem and a high voltage test bench with electrical power source and load simulators to support development, operation, payload accommodation, and anomaly investigation of manned space electrical systems. A computer-based laboratory data management system gathers, records, and displays parametric data from an array of sensors spread throughout the system. Computer workstations using math models and software-developed programs provide a system for developing data and control interfaces.

has been upgraded to support new orbiter development. It is presently being used for operational evaluation of flight-type hardware, payload interface tests, and anomaly investigations. The high voltage test bench provides a resident JSC electrical power test system to support Space Station Freedom and other tasks that involve advanced development techniques. Electrical power transfer techniques such as those for the orbiter and Space Station Freedom will be tested and evaluated using the Shuttle breadboard and high voltage simulators.

The laboratory is equipped with special power supplies, power source simulators, electrical load simulators, a wide variety of standard and specialized test equipment, computer-based workstations, and an integrated computerized data retrieval and management system. Direct-current power supplies can deliver regulated direct-current power up to five hundred amperes each at thirty-two volts direct current. Programmable alternating current sources provide up to nine kilovoltamperes of three-phase, alternating-current power with programmable amplitude, phase, and frequency variations. Power source simulators are capable of simulating fuel cell characteristics at current ratings up to five hundred amperes at thirty-two volts direct current. A variety of electrical alternating-current, direct-current, and motor-load banks (some programmable) provide required electrical loads. Control panels and consoles provide a means of controlling the electrical power through the breadboard portions of the laboratory, while instruments monitor the various electrical parameters such as voltage, current, frequency, phase angle, and power factor. A dynamometer system can test and

DESCRIPTION: The Electrical Power Systems Laboratory includes a Shuttle electrical power distribution and control breadboard, a high voltage test bench, and a laboratory data management system. The Shuttle breadboard (reconfigurable)

**evaluate small electrical motors with different horsepower and revolutions-per-minute ratings.** The laboratory data management system with its computer and various peripherals provides a fast, accurate means of gathering and recording data while performing various analytical functions needed for total power system performance evaluations. Computer-based work stations are used to develop and test math models and simulators of electrical systems to support interface development techniques.

The different segments of the laboratory provide the flexibility to support the development and evaluation of large space electrical power distribution and control systems and the evaluation of subsystems, black boxes, and components.

**DATA ACQUISITION:** Data management is described where appropriate in the above facility specification; see also the Data Acquisition section under the Thermochemical Test Area.

## General Facility Specifications

### THERMOCHEMICAL TEST AREA

LOCATION: Buildings 350, 351, 352, 353, 354, 355, 356, 356E, and 359

DESCRIPTION: The Thermochemical Test Area, located on 465 405 square meters in the northwest corner of JSC, consists of five independent test facilities along with supporting laboratories:

POINT OF CONTACT: Chief, Thermochemical Test Branch, Code EP6, (713) 483-4513

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$5,000k

REPLACEMENT COST: \$26,000k

USE: Consisting of five independent test facilities along with supporting laboratories, the Thermochemical Test Area has been utilized since 1964 to provide subsystem and component test support for propulsion and power subsystems utilized in United States manned space programs. For the Space Shuttle program, this support includes flight anomaly investigation; a limited number of qualification programs in areas where the contractors lack adequate facilities; low temperature qualification of the NASA Standard Initiator (Government-furnished equipment item); distribution, maintenance, and repair of the Initiator Resistance Measuring Equipment and the Initiator Firing Unit (Government-furnished equipment items); acceptance tests of liquid hydrogen recirculation pumps; and shelf-life and cycle-life tests of pyrotechnics, batteries, and overwrap pressure vessels.

- Thermal Vacuum Test Facility
- Pyrotechnics Test Facility
- Propulsion Test Facility
- Power Systems Test Facility
- Fluid Systems Test Facility

In addition, the Thermochemical Test Area facilities include central laboratories which provide support for electrical and mechanical systems, equipment fabrication, chemical analysis, system cleaning and assembly, instrumentation calibration, and data acquisition and reduction. The dedicated facilities and support laboratories provide the capability for rapid response in the investigation of real-time problems and flight anomalies.

#### General Features of the Test Facilities

Each of the Thermochemical Test Area test facilities has storage and transfer systems for thermal conditioning, cold trapping, and purging. Each has small, dedicated mechanical and electrical shops for buildup of test systems. These shops are equipped for tube bending and flaring, electrical cable fabrication, etc.

**Three of the test facilities (Buildings 353, 354, and 356) are served by a process waste sewer that carries propellant bearing waste water to a treatment impoundment at Building 358 and a meteorological station that provides data to ensure that propellant operations can be conducted safely.**

The two test facilities that work with the space storable rocket propellants (Buildings 353 and 356) are equipped with water-pumped, breathing-air systems, safety showers, oxidizer burners, and fuel scrubbers.

Each test facility in the Thermochemical Test Area has specialized safety equipment specifically suited for its test operations. This equipment includes fire detectors, hydrogen sensors, grounding straps, conductive floors, acid suits, toxic vapor detectors, cryogenic gloves, face shields, and safety glasses. With the exception of the Thermal Vacuum Test Facility (Building 351), all test facilities are constructed of one-foot-thick, heavily-reinforced concrete for blast protection. This reinforcement allows facility control rooms to share a common wall with many test cells where the close proximity supports measurements of low-level signals and minimizes test buildup time.

**DATA ACQUISITION:** Centrally-located control rooms are used for remote control of all hazardous testing in the Thermochemical Test Area. Each test facility has dedicated data

acquisition and computing systems with recording and display capability. Data reduction services are located at Building 351. Portable four-channel digital recording oscilloscopes can sample at a rate of ten million times a second and provide playback in an analog format.

High speed digital memory units can be triggered to record up to eight channels at high speed and play back data on strip charts at an equivalent real-time chart paper speed of 1609 meters per second.

High frequency response multipen strip charts provide real-time analog format data as required.

Television monitors and high speed film cameras can be used for visual investigations of difficult-to-instrument phenomena. Vibration analyzing equipment is available for the detection of instabilities, bearing problems, and destructive resonance.

Instrumentation and signal conditioning for all basic test parameters are available in the Thermochemical Test Area, including strain-gage and water-cooled piezoelectric thrust and load transducers; drag body, Vol-o-Flo, thermal mass flow, and turbine flowmeters; and resistance temperature measurement devices and thermocouples of all types.

## General Facility Specifications

### THERMAL VACUUM TEST FACILITY

LOCATION: Building 351

POINT OF CONTACT: Chief, Thermochemical Test Branch,  
Code EP6, (713) 483-4513

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$810k

REPLACEMENT COST: \$5,000k

USE: The Thermal Vacuum Test Facility was designed to accomplish complex tests on a spacecraft subsystem in a high vacuum and a selectable thermal environment. A 4.6 meter diameter thermal vacuum chamber and a smaller, 0.76 cubic meter thermal or vacuum chamber provide for flexible and economical test operations. An electromechanical actuator testbed and slaved hydraulic power unit provide the capability to investigate new equipment in the area of advanced technology. Building 351 also houses the Propulsion and Power Division's VAX computer. This computer is used for data reduction purposes in support of all Thermochemical Test Area testing facilities.

DESCRIPTION: The Thermal Vacuum Test Facility (Building 351) has two floors adjacent to a high bay that is outfitted with two thermal vacuum chambers. The second floor houses the

Propulsion and Power Division's VAX computer and Thermochemical Test Area central data reduction services, as well as the test facility data acquisition and control room. The control room shares a wall with the high bay. This common wall is masonry with a 0.00635-meter-thick, steel plate backing. Other construction at this facility is ordinary (nonblast).

The southwest corner of the first floor is a test bay with a 7457 watt electromechanical actuator testbed. The testbed is served by a 44 742 watt hydraulic power unit and cooling tower outside of the building.

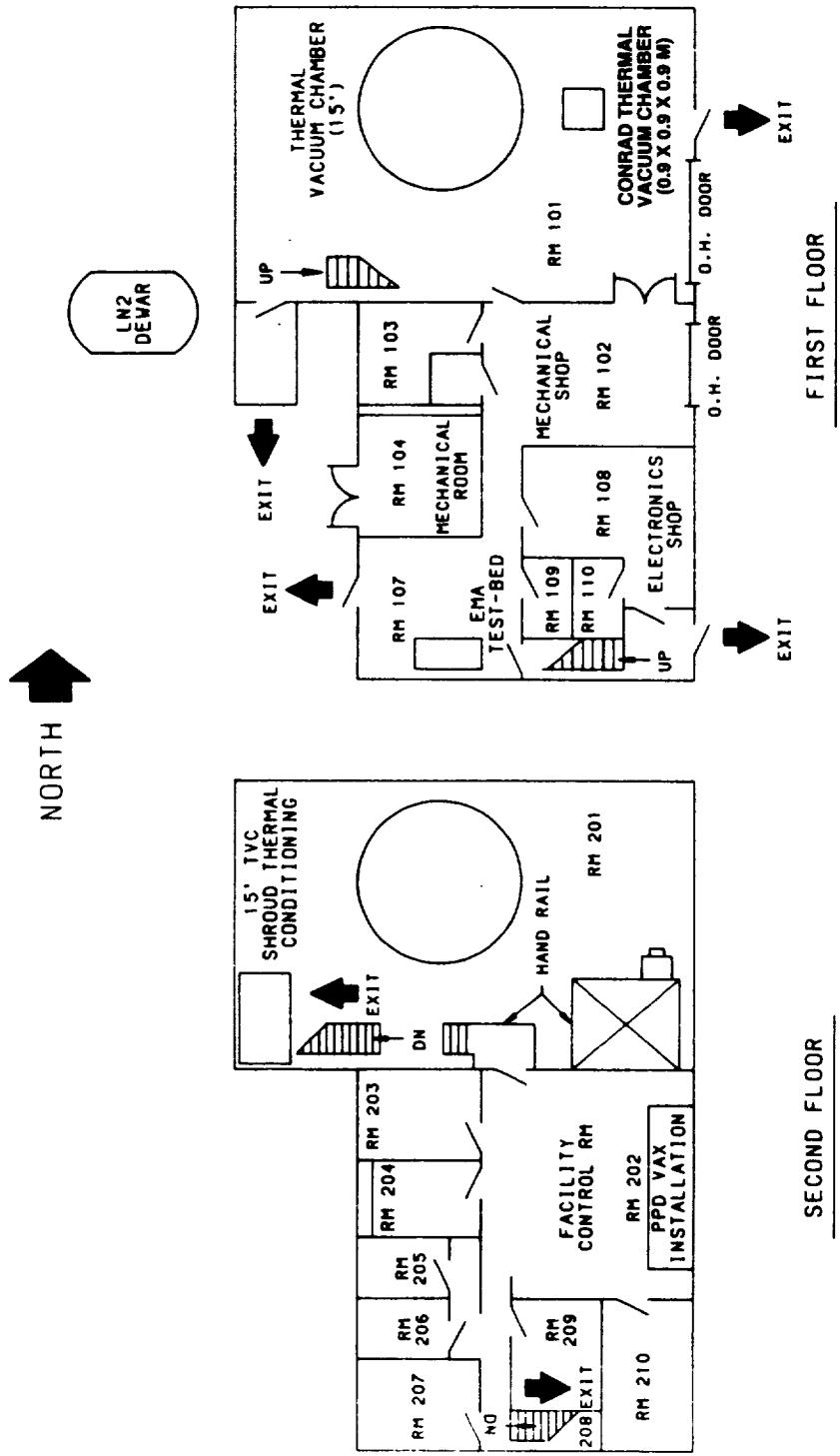
A 4.6 meter diameter spherical thermal vacuum chamber in the high bay of the facility offers 0.00133 pascal vacuum and shroud temperatures from minus 6.67 degrees Celsius to plus 149 degrees Celsius. The usable interior diameter is 3.8 meters. Test articles must pass through a two meter diameter door. Entry to the chamber is from a mezzanine floor that spans most of the high bay. An overhead crane serves in door removal and test article installation. This chamber has two fifty-thousand-liters-per-second diffusion pumps backed by a 2.36-cubic-meter-per-second, roots-type blower and a 0.40-cubic-meter-per-second mechanical pump.

A packaged Conrad thermal or vacuum chamber occupies a part of the high bay, below the mezzanine. This chamber has an .085 cubic meter test space having an ultimate vacuum capability of 0.00133 pascal and a thermal capability of minus 11.7 degrees Celsius to plus 260 degrees Celsius when

chamber pressure is above 11 600 pascals. Thermal control is primarily by forced convection and is thus unavailable at ultimate vacuum.

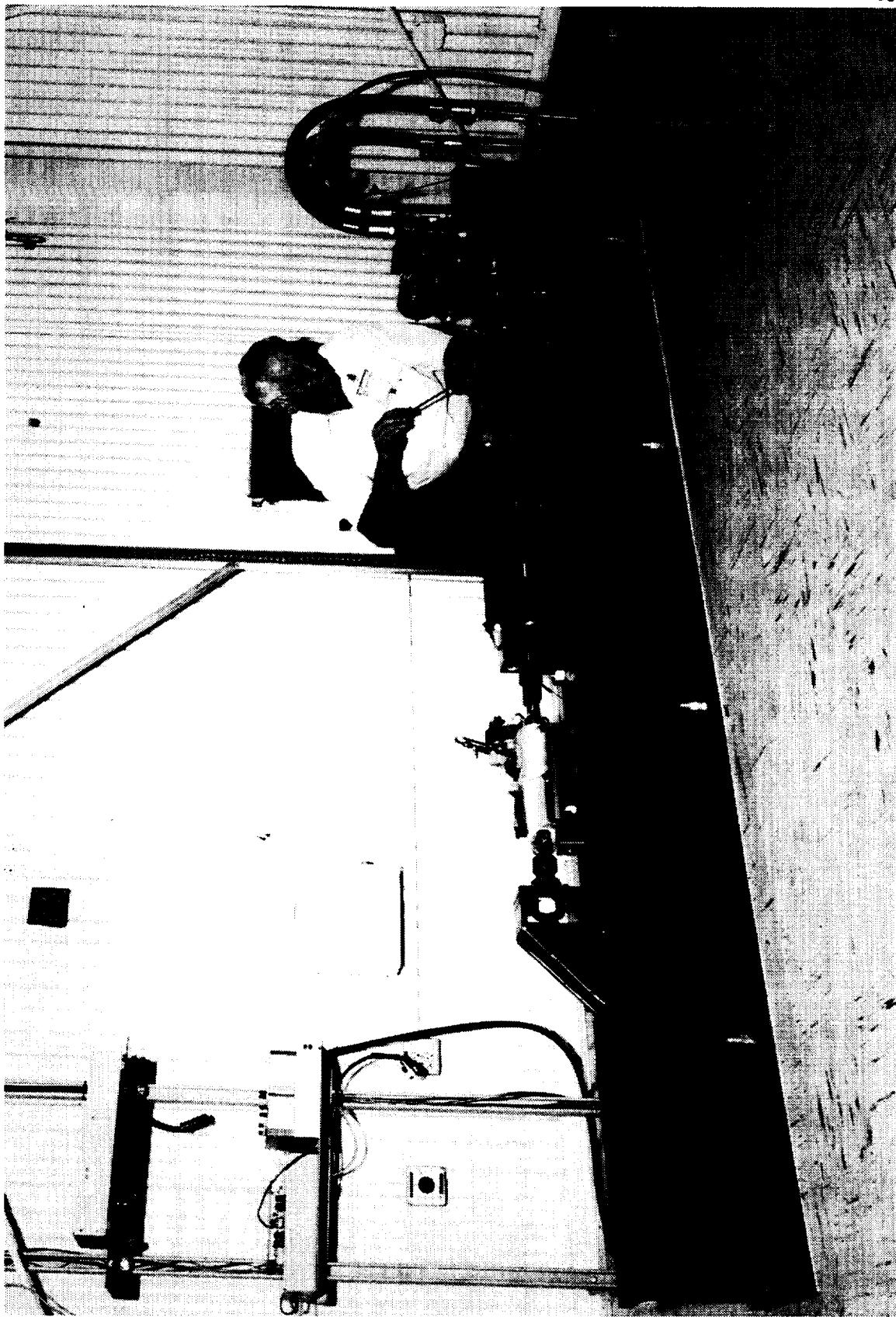
( )  
DATA ACQUISITION: Data management is described where appropriate in the above facility specification; see also the Data Acquisition section under the Thermochemical Test Area.

## BUILDING 351: THERMAL VACUUM TEST FACILITY



ORIGINAL PAGE  
BLACK AND WHITE PHOTOGRAPH

ELECTROMECHANICAL ACTUATOR TEST BED OPERATIONS AT BUILDING 351



S91-53398

## General Facility Specifications PYROTECHNICS TEST FACILITY

LOCATION: Building 352

is equipped for altitude, temperature soak, electrical characteristics, vibration, and shock testing.

POINT OF CONTACT: Chief, Thermochemical Test Branch,  
Code EP6, (713) 483-4513

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$543k

REPLACEMENT COST: \$3,000k

USE: The Pyrotechnics Test Facility evaluates the performance of pyrotechnic devices, high-energy density batteries and cells, and other components and subsystems used for flight and ground support. Additionally, this facility provides maintenance, calibration, and field engineering support for the initiator resistance measuring equipment and the initiator firing units that are used at all NASA centers and by pyrotechnic contractors. The facility is used for low temperature qualification testing of the NASA standard initiator (Government-furnished equipment) and is the storage and distribution center for all high energy batteries at the JSC.

DESCRIPTION: The Pyrotechnics Test Facility provides the capability for storage, loading, unloading, and testing of pyrotechnic devices. Additionally, it has the capability for hazardous testing of high-energy-density batteries and cells. It

The facility includes electronic and mechanical shops, a control room, office space, an explosives loading and handling room, remote test cells for hazardous testing, and a vibration test cell. Pyrotechnic storage is provided by four earth-covered bunkers.

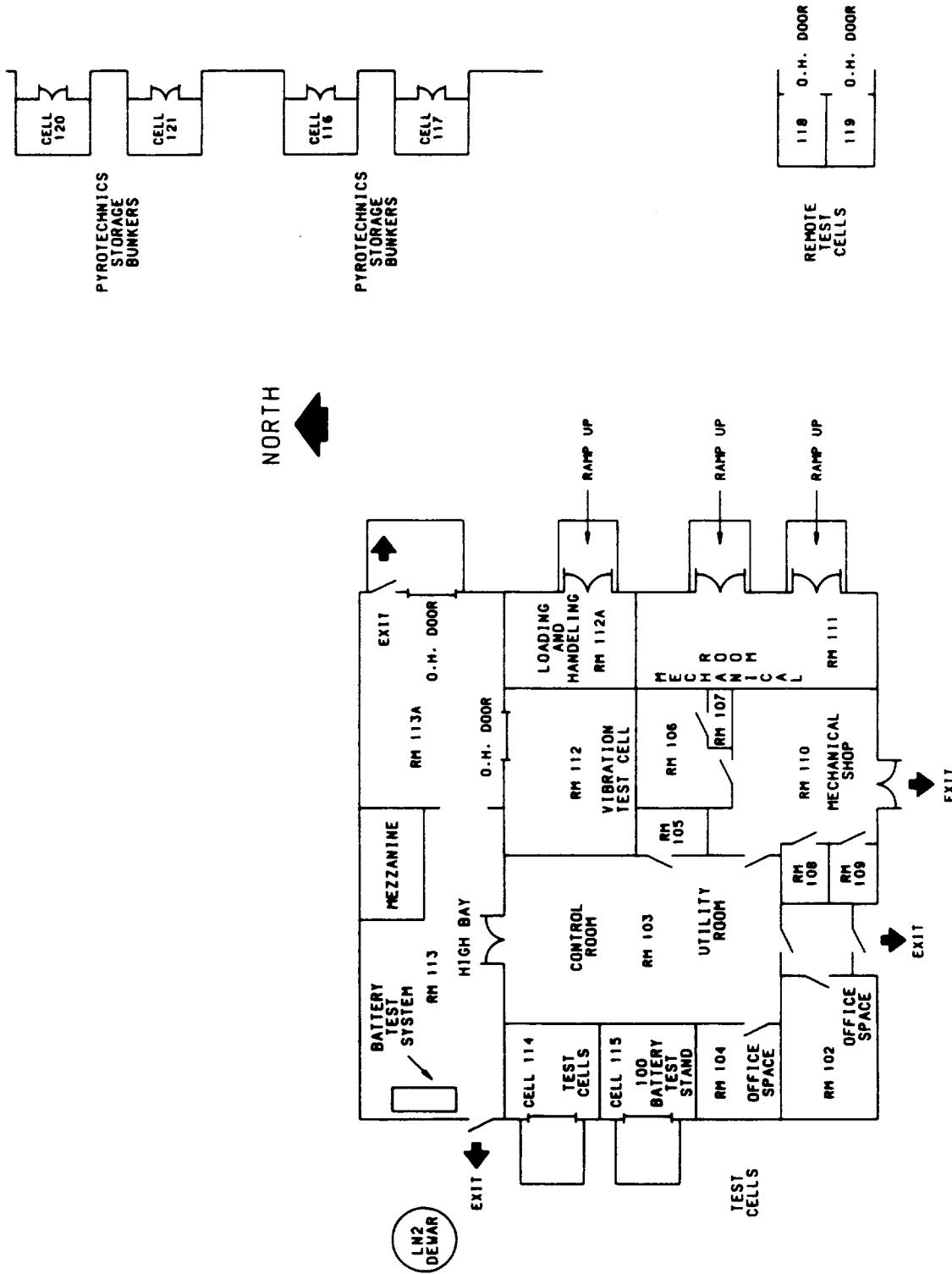
Specific facility and equipment capabilities are as follows:

- A computer controlled vibration system provides both sine and random vibration testing. Vibration levels of 4989 gravity-kilograms over a frequency range of five- to three-thousand hertz can be obtained on the Remote Manipulator System.
- A testbed containing three chambers (0.254 meter diameter by 0.457 meter deep) is rated from vacuum to 689 476 pascals maximum allowable working pressure with an independent environmental conditioning system (minus 62.2 to plus 148.9 degrees Celsius). It has a dedicated digital data acquisition system and electrical load banks. This testbed is used primarily for high-energy density batteries and cells, and each chamber can handle nine batteries or cells.
- An ambient battery and cell testbed is capable of discharging one hundred units simultaneously. It is computer controlled and able to monitor unit health and profile loads, as needed. It has its own dedicated digital data acquisition system, relay-operated load banks, and is thermally conditioned to 23.9 plus-or-minus 5.56 degrees Celsius. This testbed can be

- used with all types of batteries and cells, including high energy lithium cells.
- Two thermal chambers for testing small components have a temperature range from minus 73.3 to plus 176.7 degrees Celsius and a 0.0283 cubic meter test area.
- A shock testing machine is capable of accommodating test specimens up to 15.9 kilograms in weight and 0.222 by 0.254 meters in size. It provides a maximum drop height of 1.17 meters. The machine is capable of producing half sine and sawtooth wave shapes. Acceleration ranges from the gravity force of two thousand at 0.5 millisecond to one hundred gravity at eleven millisecond in the half-sine mode. A sawtooth kit is provided that will produce 6.5 millisecond pulses of fifteen to 110 gravity.
- A low-temperature conditioning chamber has a work space of approximately 0.34 cubic meters and a temperature range from ambient to minus 149 degrees Celsius when using liquid nitrogen.

- A high- and low-temperature conditioning chamber has a work space of approximately 0.59 cubic meter and a temperature range from minus 37.8 to plus 199 degrees Celsius.
  - A metallurgical grinder polisher is used for investigation of the internal components or initiators and other small explosively operated devices.
  - A helium leak detection system is capable of detecting at least one part of helium in ten million parts of air.
  - A lathe with special protective shields can be used for disassembly of pyrotechnic devices.
- DATA ACQUISITION: Data management is described where appropriate in the above facility specification; see also the Data Acquisition section under the Thermochemical Test Area.

## BUILDING 352: PYROTECHNICS TEST FACILITY



VIBRATION TESTING AT BUILDING 352



## General Facility Specifications PROPELLION TEST FACILITY

LOCATION: Building 353

by two stages of steam ejection, cooled by open barometric condensers.

POINT OF CONTACT: Chief, Thermochemical Test Branch,  
Code EP6, (713) 483-4513

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$899k

REPLACEMENT COST: \$4.7M

USE: The Propulsion Test Facility conducts research on, as well as development and qualification testing of, gaseous and liquid rocket engines, of auxiliary propulsion units, and of Space Shuttle subsystems and components under sea level and simulated altitude conditions.

DESCRIPTION: The Propulsion Test Facility has the capability for both sea level and altitude testing of rocket engines and Shuttle subsystems under simulated thermal vacuum conditions.

A single-engine, horizontal-firing, altitude test chamber provides 30 480 meters simulated altitude for testing of reaction control rocket engines. A custom, tandem diffuser-ejector (first stage steam ejector) provides a continuous altitude environment regardless of engine duty cycle, a necessary feature for reaction control engine testing. The diffuser-ejector is backed

A 6.1 meter diameter subsystem altitude test chamber is used for breadboard or integrated systems testing that requires a single or multiple rocket engine firing capability. The Space Shuttle auxiliary propulsion unit has been tested in this chamber extensively. This chamber is a rugged vacuum test chamber built to contain explosive reactions should they occur. Two pumping systems serve the chamber. One is a mechanical pumping system capable of maintaining the environment at a 51 816 meters simulated altitude for system testing. The other is a three-stage steam ejection system capable of maintaining 30 480 meters altitude during "normal" pulse mode testing of multiple 445 newtons hypergolic or monopropellant thrusters. Portable thermal panels within the chamber can provide local thermal environments ranging from minus 53.9 to plus 149 degrees Celsius.

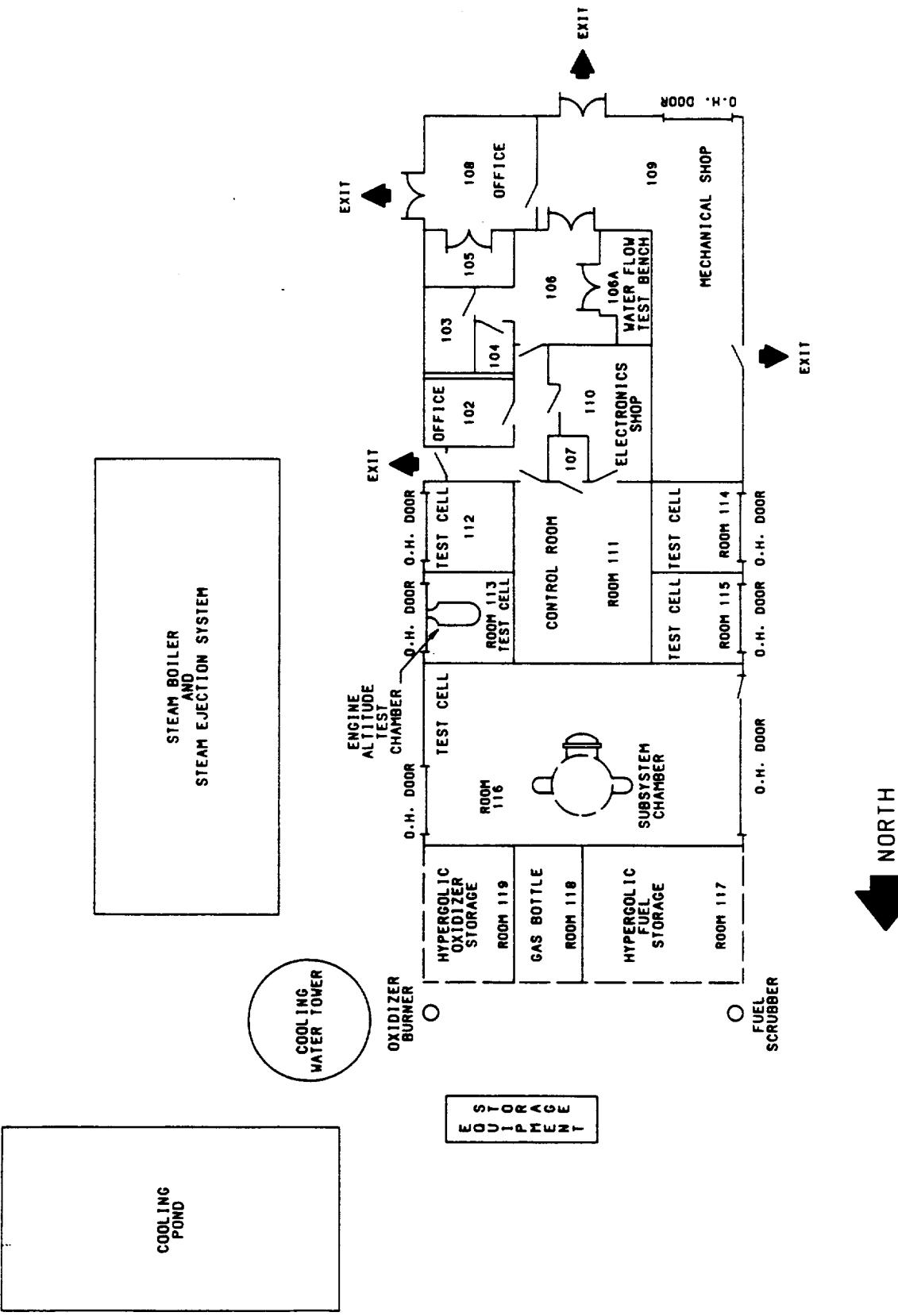
Propulsion test stands and chambers can be used with propellants other than the Earth storables utilizing portable or mobile propellant supplies.

The Propulsion Test Facility has a saturated steam boiler capable of supplying 7.55 kilograms per second at 2 068 500 pounds to the two altitude chamber steam ejector systems. High-pressure helium and nitrogen supplies are available for pressurizing and purging the propellant systems or actuating high-speed valving.

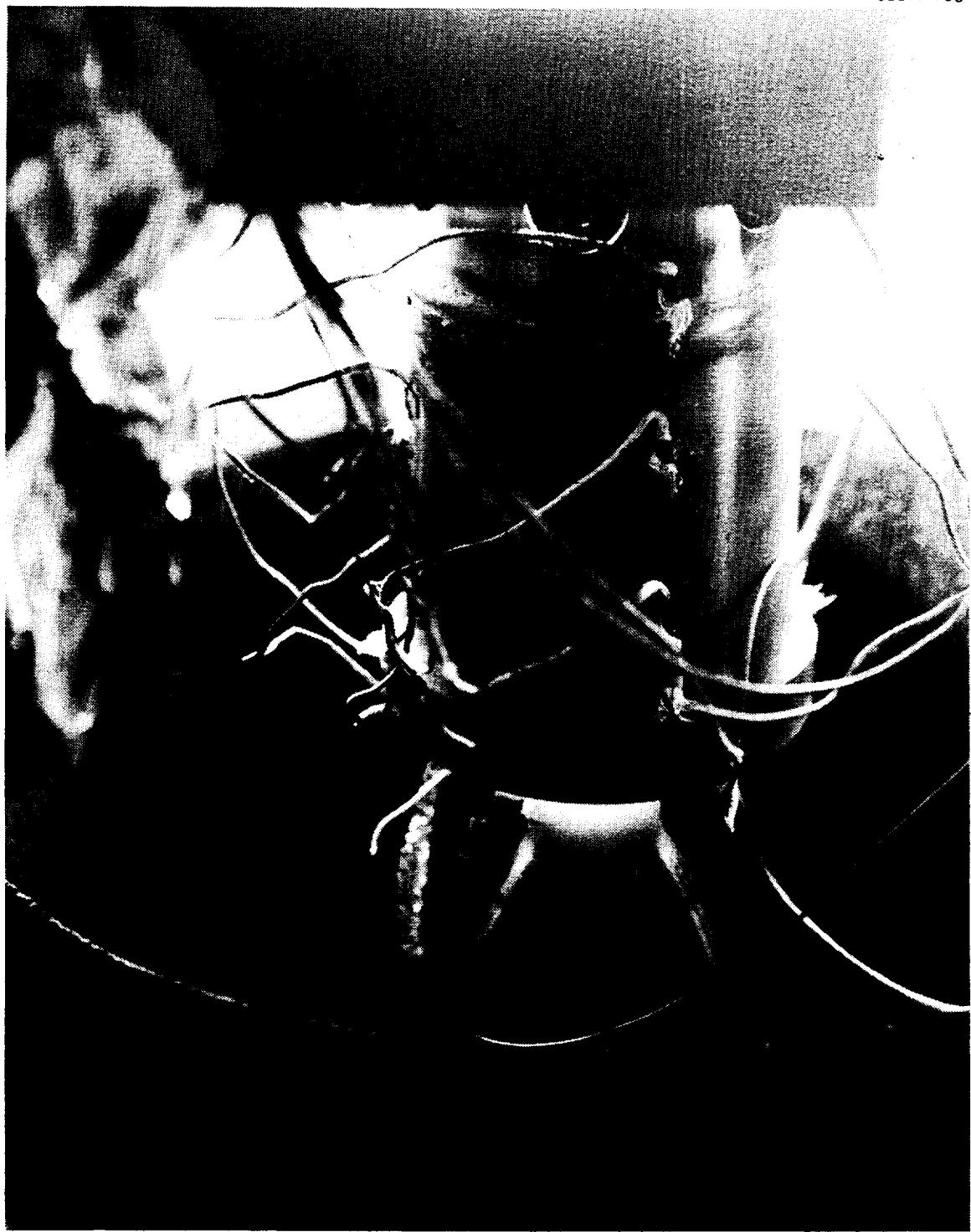
A water flow, leak, and functional test bench is used for check-out of valves, injectors, and other components. Flows to 0.000946 cubic meters per second and pressures to 9 997 750 pascals are available.

DATA ACQUISITION: Data management is described where appropriate in the above facility specification; see also the Data Acquisition section of the Thermochemical Test Area.

## **BUILDING 353: PROPULSION TEST FACILITY**



**ROCKET ENGINE ALTITUDE TESTING AT BUILDING 353**



## SUBSYSTEMS ALTITUDE TEST CHAMBER OPERATIONS AT BUILDING 353



S92-28673

## **General Facility Specifications**

### **POWER SYSTEMS TEST FACILITY**

**LOCATION:** Building 354

**POINT OF CONTACT:** Chief, Thermochemical Test Branch,  
Code EP6, (713) 483-4513

**STATUS:** Operation: Active, Control: JSC and Contractor,  
Owner: JSC

**YEAR BUILT:** 1964

**INITIAL COST:** \$566k

**REPLACEMENT COST:** \$3,000K

**USE:** The Power Systems Test Facility is designed to support engineering developmental testing on spacecraft electrical power generation systems and cryogenic fluid components. It provides the capability of supporting thermal, transient, life expectancy, optimization, and failure mode investigation of power generation systems and components for cryogenic systems. Building 354 has the only capability for acceptance testing of the main propulsion system hydrogen recirculation pump used in the orbiter.

**DESCRIPTION:** The Power Systems Test Facility is designed to support research and development of spacecraft electrical power generation systems and cryogenic system components.

One of two test cells on the east side of Building 354 is dedicated to life cycle testing of flight weight pressure vessels. The other is a general purpose test cell. A test cell slightly north of Building 354 is environmentally-conditioned and equipped for fuel cell and electrolysis testing.

A major asset of this test facility is a liquid hydrogen pump flow test stand. This test stand consists of a 1.89 cubic meter supply tank; a 0.0126 cubic meters per second circulation pump; an external flow loop; and return piping that reenters the supply tank and contains an internally mounted flowmeter and remotely operated flow control valving.

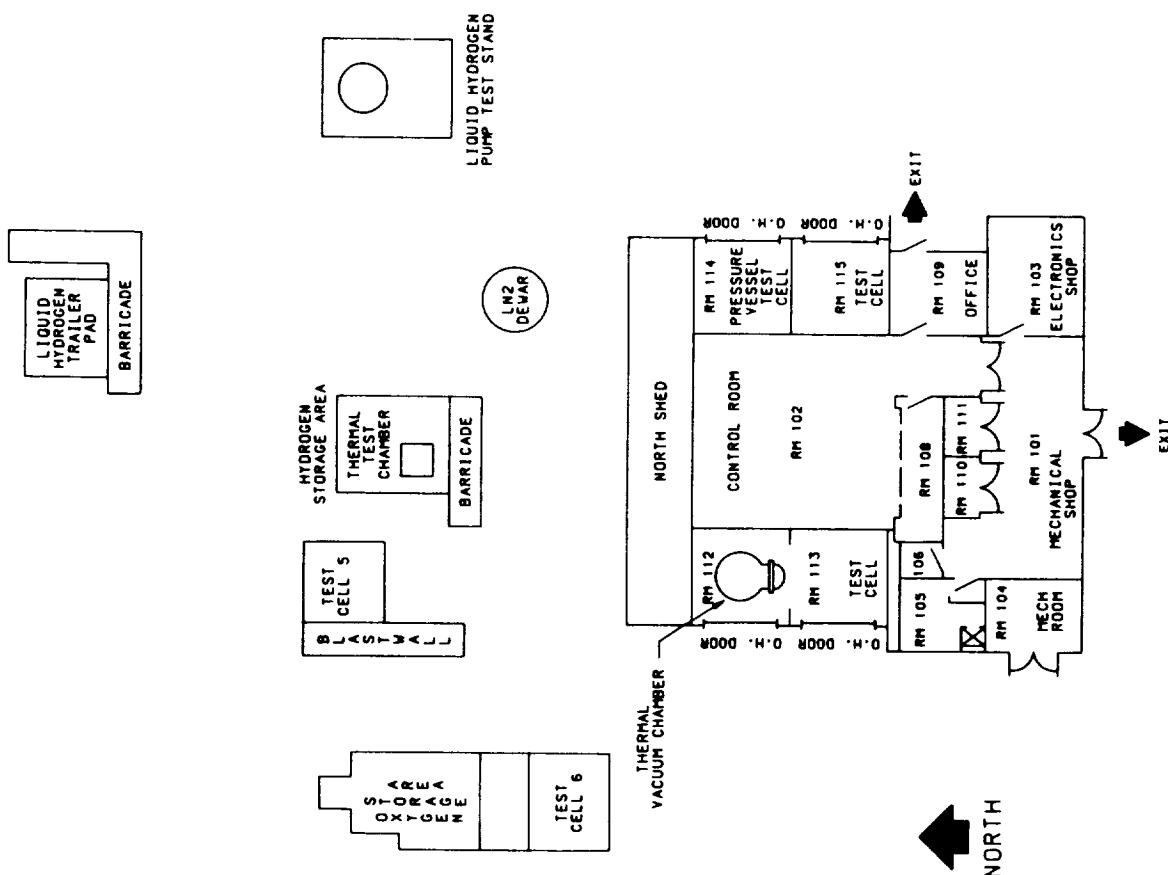
The facility contains three load panels capable of manually or automatically inducing various increments of resistive loads. A transient load programmer is capable of switching electrical loads from one hundred to 7500 watts in one hundred watt increments with switching times of approximately one hundred microseconds. This programmer is used to evaluate the transient electrical response characteristics of a power generation system when subjected to short duration (spike) step load changes.

Liquid hydrogen is stored in portable 3.79 and one cubic meter hydrogen storage dewars, and liquid oxygen is stored separately in a portable 0.95 cubic meter oxygen storage dewar. A remote, barricaded trailer pad can be used for supply of liquid hydrogen to the facility dewars or the pump test stand from a 47.3 cubic meter road trailer.

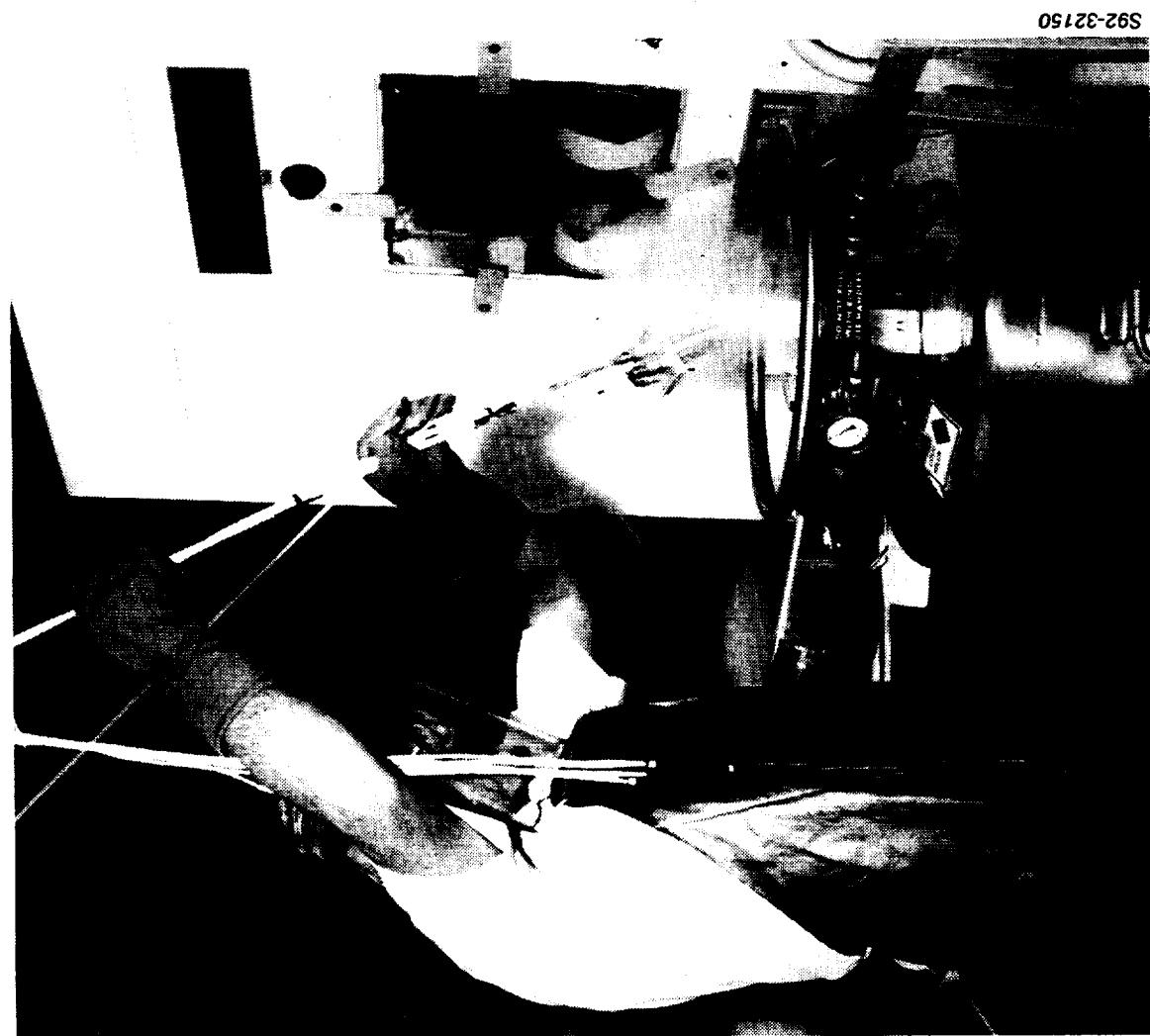
A vertical, cylindrical thermal vacuum chamber that is 2.4 meters in diameter and 2.4 meters tall is installed in a test cell on the west side of Building 354. It permits system evaluation programs in a simulated space environment. The thermal environment in the chamber can be varied from minus fifty-one to plus 121 degrees Celsius while maintaining a vacuum level of approximately 0.000133 pascal.

A thermal chamber permits evaluation testing of cryogenic storage systems in a temperature-controlled environment. The chamber provides temperature control from minus 34.4 to plus 121 degrees Celsius in a working volume that is approximately 2.1 by 1.8 by 1.8 meters.

## BUILDING 354: POWER SYSTEMS TEST FACILITY

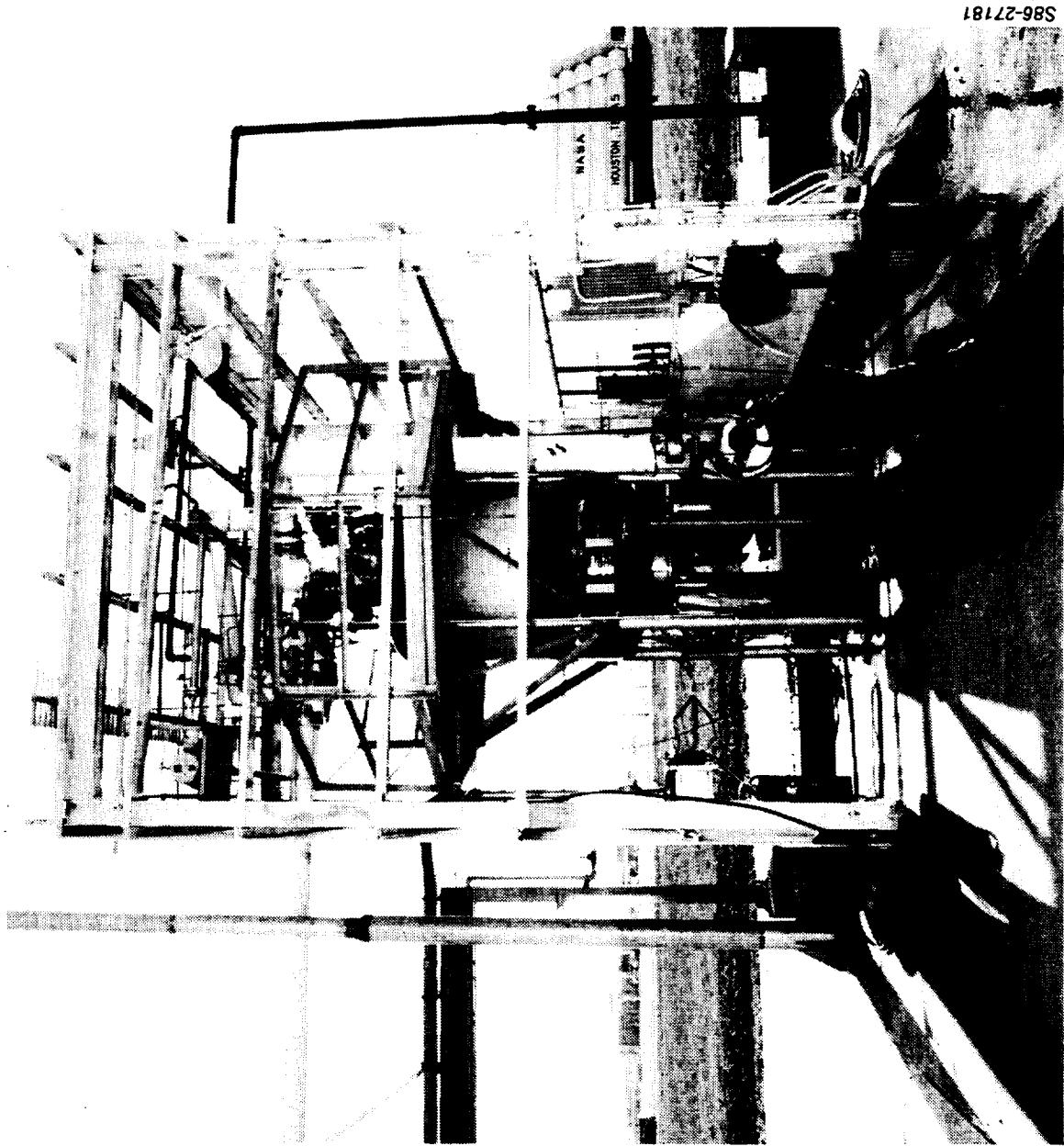


## CRYOGENIC TEST OPERATIONS AT BUILDING 354



S92-32150

**HYDROGEN PUMP TEST STAND OPERATIONS AT BUILDING 354**



## General Facility Specifications

### FLUID SYSTEMS TEST FACILITY

LOCATION: Building 356

POINT OF CONTACT: Chief, Thermochemical Test Branch,  
Code EP6, (713) 483-4513

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$1,427k

REPLACEMENT COST: \$7,400k

USE: The Fluid Systems Test Facility has the capability to support spacecraft fluid system tests requiring a variety of fluids and temperature or vacuum conditioning. Special emphasis is placed on propulsion fluid systems testing. Testing includes that of component and system cold flow; compatibility, leakage, and dynamic response; testing of secondary batteries for cycle life capacity and acceptance; proof and pressure testing; and investigation of flight anomalies of spacecraft propulsion systems.

DESCRIPTION: The Fluid Systems Test Facility (Buildings 356 and 356E) consists of three flow test cells, a secondary battery test stand, a thermal vacuum test chamber, two thermally controlled compatibility test cells, hypergolic propellant storage areas, and a test operations control center.

Building 356 has a water flow test system capable of flow rates to 0.0379 cubic meters per second, consisting of a supply and receiver vessel and dedicated test cell with flow control valving and pressure, temperature, and flow instrumentation. This water flow test system has an additional catch-and-weigh system for verification of pulse-mode flow measurement. This system can handle flows of up to 0.00757 cubic meters per second and provide continuous readout of mass flow. A gas injection system provides the capability to test the flowmeter's ability to measure liquid flow under two-phase flow conditions. A portable water flow prover with similar two-phase flow calibration capability is available for "zero-g" testing aboard NASA's KC-135 Reduced Gravity Aircraft. Building 356 has two separate, dedicated gas supply systems (helium and nitrogen), with operating pressures of up to 22 753 500 pascals gauge and volumes to 326 cubic meters. In addition, a trailer supplied gas system provides 31 027 500 pascals gauge helium to a Shuttle Main Propulsion System Helium System test stand.

Building 356 also has a thermal vacuum test chamber 1.5 meters in diameter with a 1.5-meters-long working space. The thermal environment is controllable from minus 184 to plus 177 degrees Celsius, plus or minus 2.2 degrees Celsius, and a vacuum down to 0.0000013 pascal can be achieved.

Building 356E has a helium (or nitrogen) gas supply system containing 340 cubic meters that can supply pressures of up to 45 507 000 pascals gauge. It also has trailer-supplied hydrogen and oxygen systems with small (0.0000041 cubic meters per

second) displacement compressors (two hydrogen and one oxygen) for 20 685 000 pascals gauge delivery to supply tanks for a sea level, two-position, twenty-two-newton-thrust, oxygen and hydrogen rocket engine test stand.

Short-term or long-term compatibility testing for the hypergolic propellants or other corrosive fluids can be accomplished in

Building 356E in the two compatibility test cells. The two cells include a large high-bay cell six by 6.7 by six meters and a smaller cell 4.3 by 3.4 by three meters. Both cells are environmentally controllable between 4.4 and sixty degrees Celsius, plus or minus 1.1 degrees Celsius.

## BUILDING 356: FLUID SYSTEMS TEST FACILITY

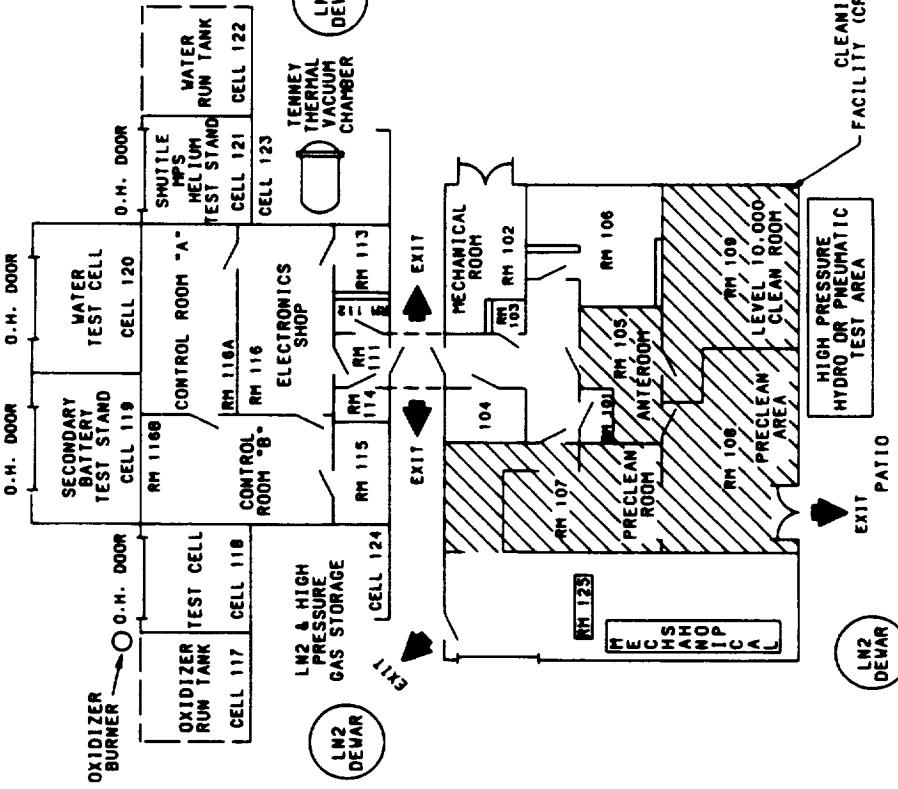
**OXIDIZER**  
STORAGE AREA  
LOCATED 91.4 M  
NORTHEAST  
FROM BUILDING 356



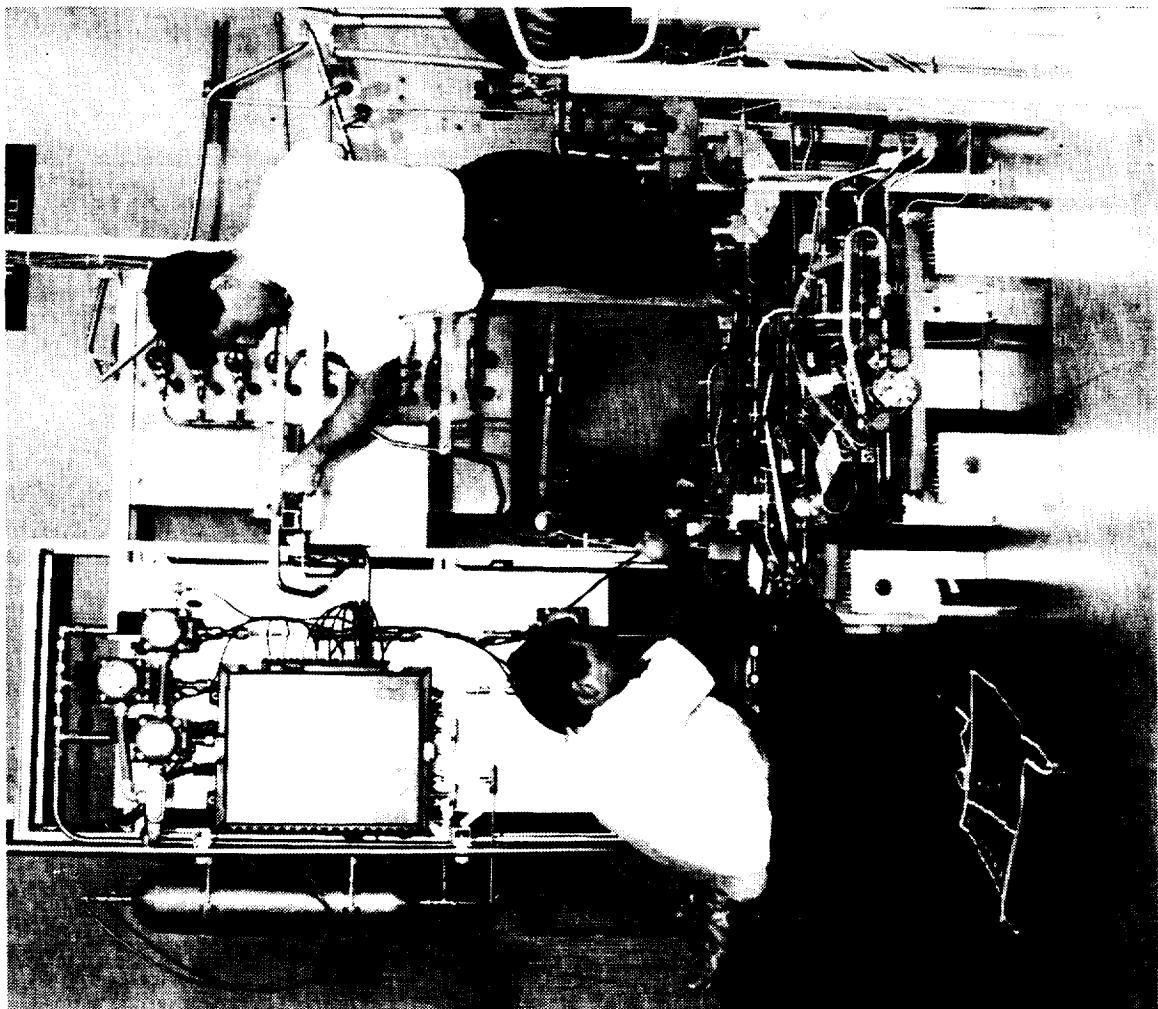
FUEL SCRUBBER  
O

NORTH  
→

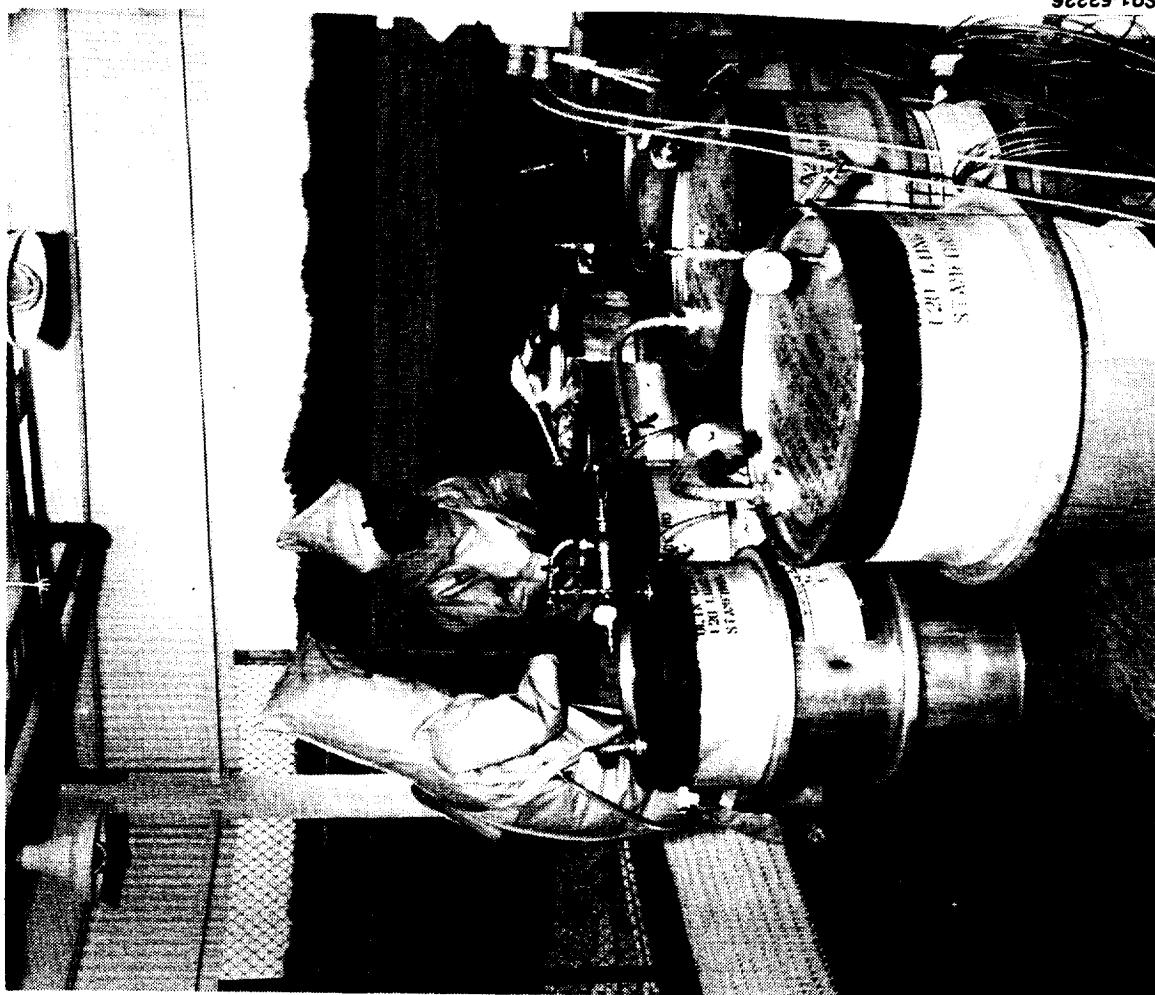
BLAST WALL



**MAIN PROPULSION SYSTEM HELIUM TEST STAND OPERATIONS AT BUILDING 356**



## HYPERGOLIC PROPELLANT OPERATIONS AT BUILDING 356



## Chapter 6

### AUTOMATION AND ROBOTICS DIVISION (ER)

#### Contents

FACILITY	PAGE
Laboratory Support . . . . .	6-3
Intelligent Systems Laboratory . . . . .	6-5
Integrated Graphics Operations and Analysis Laboratory . . . . .	6-7
Robotic Systems Evaluation Laboratory . . . . .	6-9
Dexterous Robotics Laboratory . . . . .	6-10
Mobile Robotics Laboratory . . . . .	6-12
Telepresence Laboratory . . . . .	6-13
Robotic Sensor Integration Laboratory . . . . .	6-14
Space Systems Automated Integration and Assembly Facility . . . . .	6-15
Manipulator Development Facility . . . . .	6-17
Electronics Development Laboratory . . . . .	6-18

support such future programs as the Space Exploration Initiative.

Division programmatic support covers the complete spectrum of activities from requirements generation and conceptual design through design, development, verification, training, and operational support. Notable specific programmatic support assignments include the following:

- Subsystem Management for the Shuttle Remote Manipulator System and for the associated grapple fixtures
- Management of a variety of hardware functions associated with the Space Station including integration of the Mobile Servicing Center System, subsystem management of the Mobile Transporter Element, integration of the Special Purpose Dexterous Manipulator, Grapple Fixture Subsystem management, and robotic maintenance verification
- Management of the development, integration, test, and verification of the Space Station Integrated Station Executive software which provides overall command and control capability for the Space Station

#### Overview

The Automation and Robotics Division supports NASA by providing current and advanced software tools, applications, and systems. The division provides hardware components and systems in the areas of automation and intelligent systems and telerobotics and autonomous robotic systems for both ground and space flight applications.

The division supports all major programs assigned to JSC, including the Shuttle and Space Station Freedom, and will

The division defines, develops, and demonstrates advanced technology concepts in the areas of automation and intelligent systems, as well as in telerobotics and autonomous robotic systems. The division also develops and carries out flight experiments in these areas.

The Automation and Robotics Division operates and maintains a set of laboratories for in-house development and test purposes to aid in the accomplishment of its programmatic, advanced

**technology, and flight experiment responsibilities.** These laboratories are the following:

- Intelligent Systems Laboratory
- Integrated Graphics Operations and Analysis Laboratory
- Robotic Systems Evaluation Laboratory
- Dexterous Robotics Laboratory
- Mobile Robotics Laboratory
- Telepresence Laboratory
- Robotic Sensor Integration Laboratory
- Electronics Development Laboratory

The division operates and maintains the Space Systems Automated Integration and Assembly Facility to provide full-scale integrated, closed-loop dynamic testing of the construction, assembly, and robotic maintenance of the Space Station, as well as spacecraft, structures, and components for future programs.

**The division operates and maintains the full-scale Space Shuttle Program Manipulator Development Facility to provide flight crew training, systems development, and operations support activities.**

- The division is developing and will operate and maintain the full-scale Space Station Freedom Program Mobile Remote Manipulator Development Facility to provide flight crew training, systems development, and operations support activities.

The division maintains a centralized computer-aided design capability to support all division laboratories, facilities, and programs.

By virtue of its expertise, laboratories, facilities, and responsibilities, the Automation and Robotics Division provides the major focus for automation and robotics activities at JSC, and for cooperative activities with other NASA centers and government agencies.

## General Facility Specifications

### LABORATORY SUPPORT

<u>LOCATION:</u> Building 32 and Building 9NE, High Bay and Technical Annex	<u>DESCRIPTION:</u> The Automation and Robotics Division is organized into five branches.
<u>POINT OF CONTACT:</u> Chief, Automation and Robotics Division Code ER, (713) 483-4931	The Intelligent Systems Branch (ER2) is organized into two sections and provides software development and applications management and advanced technology concepts in the areas of advanced automation and Space Station Freedom Integrated Station Executive software for overall Space Station command and control capability.
<u>STATUS:</u> Active	
<u>YEAR BUILT:</u> See description for the individual laboratory or facility	
<u>INITIAL COST:</u> See description for the individual laboratory or facility	The Flight Robotic Systems Branch (ER3) provides subsystem management and engineering analysis support for the assigned Shuttle and Space Station areas of hardware responsibility.
<u>REPLACEMENT COST:</u> See description for the individual laboratory or facility.	The Robotic Systems Technology Branch (ER4) is organized into two sections and provides technology, advanced development, and program supporting analyses in the areas of telerobotics, autonomous robotics systems, robotic intelligence, and robotic vision systems.
<u>USE:</u> Centralization and focus for robotics and advanced automation activities at JSC began with the creation of the Automation and Robotics Division on March 30, 1990. The division now provides the majority of support to all JSC automation and intelligent systems, as well as telerobotics and autonomous robotic systems for ground and space flight applications. The division supports all major programs assigned to JSC and provides technology and advanced development products and services in its areas of expertise. In order to accomplish its assigned responsibilities, the division develops, operates, and maintains a set of laboratories and facilities which are subsequently described in this document.	The Dynamic Systems Test Branch (ER5) manages the Space Systems Automated Integration and Assembly Facility and the Space Shuttle Manipulator Development Facility, both located in the Building 9NE High Bay. The Dynamic Systems Test Branch is also developing the Space Station Freedom Mobile Remote Manipulator Development Facility for test and training use in 1995. This branch also manages the Mechanical Shop in the Building 9NE Technical Annex as a service to the entire division.

The Automation and Robotics Laboratory Management Branch (ER6) **manages and operates the eight division engineering evaluation laboratories and the computer-aided design capability as a service to the division. The branch also provides analytical math modeling and simulation capability for division users.**

Subsequent entries in this catalog describe the following laboratories and facilities of the Automation and Robotics Division:

- Intelligent Systems Laboratory
- Integrated Graphics Operations and Analysis Laboratory
- Robotic Systems Evaluation Laboratory
- Dexterous Robotics Laboratory
- Mobile Robotics Laboratory
- Telepresence Laboratory
- Robotic Sensor Integration Laboratory
- Electronics Development Laboratory
- Space Systems Automated Integration and Assembly Facility
- Space Shuttle Manipulator Development Facility

The Space Station Freedom Mobile Remote Manipulator Development Facility is still in the design phase and a definitive description cannot be provided.

Future Plans: The Space Station Freedom Mobile Remote Manipulator Development Facility will be completed for use in 1996. The other laboratories and facilities will undergo normal capability growth and enhancement to maintain and increase their ability to provide effective program support.

## **General Facility Specifications**

### **INTELLIGENT SYSTEMS LABORATORY**

**LOCATION:** Building 32, Room 218

**POINT OF CONTACT:** Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** 1984

**INITIAL COST:** \$507K

**REPLACEMENT COST:** \$750K

**USE:** The Intelligent Systems Laboratory develops, collects, tests, and evaluates software tools and applications for advanced automation, expert systems, intelligent robotics, robotic perception and vision, and other artificial intelligence techniques. The laboratory facilities and assets are used for program support, technology, and advanced development purposes in fulfilling division tasks.

The Intelligent Systems Laboratory emphasizes integration of intelligent software technology into complex manned space systems. Two areas that are given special emphasis are coordination and integration of intelligent systems for safety and operator confidence. These areas respond to important concerns about the development, integration, and operation of intelligent software in manned space systems.

Systems autonomy research and development tasks include intelligent monitoring, diagnosis, situation assessment, automated knowledge acquisition and maintenance, action planning, distribution process management, distribution problem solving, and expert systems validation and explanation. Intelligent robotic research and development tasks include robotic manipulator and environment simulation, task planning, high-level object recognition, and autonomous robotic problem solving.

**DESCRIPTION:** The Intelligent Systems Laboratory provides a computing environment for development of state-of-the-art software for automation and robotics applications. The types of applications currently under development range from vision systems for robots to expert system for Space Station Freedom to user interfaces for Mission Operations. The laboratory hardware environment consists of a network of general purpose and special purpose processors.

The general purpose processors include a Digital Equipment Corporation Station 5810, a Sun 4/370 server, and a Sun 3. These machines all run the UNIX operating system. In addition, there are twelve SPARC stations. The latter provide graphics workstation access to the general purpose systems.

The special purpose processors include two personal computers (an IRIS and IRIS 4DGT), one Masscomp, and five Symbolics machines. The Iris computers are high-quality graphics systems; the Masscomp is a real-time, multicentral

**processing unit system, and the Symbolics systems are LIISP machines.**

The various systems that make up the Intelligent Systems Laboratory are networked together using Ethernet and running the Transmission Control Protocol and Internet Protocol. This network has a gateway to the JSC Engineering and Science Network, or JESNET, which in turn has a gateway to the Internet.

**The Intelligent Systems Laboratory also includes personal computers with frame grabbers used for vision work. These are Intel 386- and 486-based machines running disk operating system or OS/2 operating systems.**

## **General Facility Specifications**

### **INTEGRATED GRAPHICS OPERATIONS AND ANALYSIS LABORATORY**

LOCATION: Building 32A, Room 2009

POINT OF CONTACT: Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

STATUS: Active

YEAR BUILT: 1986

INITIAL COST: \$200k

REPLACEMENT COST: \$3,500k

USE: The Integrated Graphics Operations and Analysis Laboratory is a multifunction computer graphics laboratory which supports a wide variety of customers as well as researching and developing new algorithms in computer graphics.

DESCRIPTION: The Integrated Graphics Operations and Analysis Laboratory researches algorithms for computer graphics image generation, develops computer graphics software tools for the assessment of real-time and non-real-time space operations, generates video documentation of simulation results and conceptual scenarios, and performs man-in-the-loop systems engineering and analysis. This analysis is performed using several software packages developed by the Automation and Robotics Division (SSM, OOM, TDM, TRICK, and MAGIK) on state-of-the-art, computer graphics work stations.

The laboratory supports the Shuttle, Space Station Freedom, Space Exploration Initiative, and various other projects. The laboratory software is currently used at six NASA centers and several NASA contractor sites. Source code for some of the laboratory's products is available internationally through the Computer Software Management and Information Center, or COSMIC.

The The Integrated Graphics Operations and Analysis Laboratory equipment base includes the following:

- Silicon Graphics IRIS 4D/340 file server (one)
- Silicon Graphics IRIS 4D/310 VGX (seven)
- Silicon Graphics IRIS 4D/210 VGX (two)
- Silicon Graphics IRIS 4D/220 GTX (one)
- Silicon Graphics IRIS 4D/85 GT (two)
- Silicon Graphics IRIS 4D/70 GT (five)
- Silicon Graphics IRIS 4D/20 GT (one)
- Sun 3/260 (one)
- Sun SPARC Stations (two)
- X-Window terminals (eight)
- Apple Macintosh (one)
- Kodak XL7700 printer (one)
- Seiko CH5380 wax transfer printers (two)
- ABAKAS Digital video disk (one)
- D2 Digital video disk (one)
- Sony three-quarter inch video cassette recorder (two)
- YEM scan converters (two)
- MINI VAS single frame animation controller (one)
- VAS IV single frame animation controller and various other support equipment (one)

All of the laboratory's computers run the UNIX operating system and are networked together using Ethernet running the Transmission Control Protocol and Internet Protocol. This network has a gateway to the JSC Engineering and Science Network, or JESNET, which in turn has a gateway to the Internet.

## **General Facility Specifications**

### **ROBOTIC SYSTEMS EVALUATION LABORATORY**

**LOCATION:** Building 9NE, Technical Annex, Room 1114

**POINT OF CONTACT:** Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** 1987

**INITIAL COST:** \$1,075K

**REPLACEMENT COST:** \$1,800K

**USE:** The Robotic Systems Evaluation Laboratory's primary role is to support the Space Station Freedom Program and future programs such as the Space Exploration Initiative in developing and evaluating robotic systems and in performing assigned tasks. The Space-Station-assigned tasks include the exchange of orbital replacement units and assistance in crew work site setup and teardown. This laboratory has the capability to perform system-level testing as well as component-level testing of robotic technology. The laboratory also performs technology and advanced development tasks in support of robotics systems utilization.

**DESCRIPTION:** The Robotic Systems Evaluation Laboratory currently contains one Unimation PUMA 762 industrial robot having six degrees of freedom and two Robotic Research Corporation Dexterous Manipulators (a 1607 and a 2107) having seven degrees of freedom. These are used to investigate problems in applying telerobotics to performance of tasks in space. The robots have been used for several studies and subsequent demonstrations. Along with the above mentioned robots, the laboratory also contains the following equipment:

- IBM-XT personal computer (one)
- IBM-AT personal computer (two)
- Three-eighty-six AT personal computer (nine)
- Lord force and torque sensor, mounted on PUMA (one)
- Lord tactile array sensor (one)
- Telerobotics, Inc., force sensing gripper (two)
- Pneumatic gripper (one)
- Force and torque sensors, JR3 (three)
- IRIS workstation (two)
- Ethernet network
- Twenty by twenty video switcher and controller
- Set of six-degrees-of-freedom hand controllers (two)
- Robot workstation (two)
- Tektronic oscilloscopes (two)
- Hewlett Packard dynamic signal analyzer (one)
- Microbot teach-mover robots (two)

## General Facility Specifications

### DEXTEROUS ROBOTICS LABORATORY

LOCATION: Building 9NE, Technical Annex, Room 1113

POINT OF CONTACT: Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

STATUS: Active

YEAR BUILT: 1986

INITIAL COST: \$1,300k

REPLACEMENT COST: \$1,500k

USE: The Dexterous Robotics Laboratory focuses its suite of assets, testbeds, and equipment on the development and evaluation of dexterous robotic systems, dexterous end effectors (such as hands and grippers), and associated proximity sensing systems and vision systems. The laboratory is currently supporting the Dexterous Anthropomorphic Robotic Testbed, the Robotic Torso System Testbed, the Whole Arm Manipulator, the Xarm Testbed, and Smart Hand development. Various laboratory computers are supporting vision systems development for use with the robotic testbeds.

DESCRIPTION: The Dexterous Robotics Laboratory provides equipment and technical support for fixed-base robotics projects. Several robot arms, a robotic torso, and a variety of end effectors are located in the laboratory. Computing equipment ranging from desktop personal computers to a disk-

based, multiprocessor system is available to support various projects. Significant laboratory assets include those described below.

The Dexterous Anthropomorphic Robotic Testbed will utilize two Model 500 PUMA robots mounted on a rotating base to evaluate cooperative two-arm robotic activities. The robots will be operated by several Motorola 680xx processors located in three VME card cages along with the input and output interface cards. The system will also utilize two Sun 3 workstations and one Motorola 88000 multiprocessor system. A Data Cube vision-processing system is used to provide position information on the target object.

The Robotic Torso Testbed is a ten-degrees-of-freedom hydraulic robotic torso with two arms, which performs human-like arm and torso motions to support a variety of program and technology tasks. It consists of a Motorola 680xx processor system housed in a twenty slot VME card cage. Development and high-level control is provided by a VME resident 80386 personal computer system made by Radix Systems. Additional computing for the project is provided by a desktop personal computer.

The Whole Arm Manipulator is a high-speed, four-degrees-of-freedom robot that uses its surface as contact points for manipulation of objects. The system is housed in a twenty slot VME card cage. A software development system is resident on a 386 personal computer located in the VME card cage.

**The Xarm Testbed** is a two-dimensional arm with three degrees of freedom. The arm is controlled by a desktop personal computer using a fiber optic communication system to control the arm and transfer feedback information. The arm has been used to demonstrate the use of neural network software to control robotic arms.

The Smart Hand Development Activity includes the technology development of control systems for dexterous robotic hands supported by the Dexterous Robotics Laboratory. The laboratory provides design support, fabrication support, and equipment for the integration of computers and control electronics for a variety of dexterous robotic hands.

## **General Facility Specifications**

### **MOBILE ROBOTICS LABORATORY**

**LOCATION:** Building 9NE, Technical Annex, Room 2116

**POINT OF CONTACT:** Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** 1991

**INITIAL COST:** \$35k (Some test hardware is provided free by  
vendors or is on loan.)

**REPLACEMENT COST:** \$1,500k (not including hardware on  
loan)

**USE:** The Mobile Robotics Laboratory is the focus for  
developing and evaluating current and advanced technology  
concepts for mobile robotics platforms. The laboratory is  
capable of simultaneously supporting projects involving wheeled

robotic platforms, tracked robotic platforms, space-  
maneuverable robotic platforms (including free-flying propulsion  
systems), and legged and walking robotic platforms. Projects in  
all of these areas are in progress. Hardware components,  
hardware systems, and integrated hardware and software  
applications are tested and evaluated.

**DESCRIPTION:** The Mobile Robotics Laboratory is a  
development facility that specializes in robotic systems that have  
a means of locomotion. The assembly of hardware into  
systems is carried out in conjunction with project personnel  
from both within and outside the division. Software is integrated  
into the hardware in the laboratory and checkout and debugging  
is then performed. After development is completed, the robot  
systems are retained in laboratory inventory for future projects  
and development. Laboratory assets consist of standard  
electronic test equipment and work benches and a variety of  
personal computer workstations.

## **General Facility Specifications**

### **TELEPRESENCE LABORATORY**

LOCATION: Building 9NE, Technical Annex, Room 2110

POINT OF CONTACT: Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

STATUS: Active

YEAR BUILT: 1991

INITIAL COST: \$300k

REPLACEMENT COST: \$300k

USE: The Telepresence Laboratory is used to develop both hardware and software components and applications that will in turn be used to develop telepresence and virtual reality tools for use in a variety of advanced development and program support

tasks. Among the specialized applications of telepresence and virtual reality are simulation tasks, engineering design and evaluation of hardware designs and operational procedures, training of flight crew personnel, and training of flight control ground personnel.

DESCRIPTION: The Telepresence Laboratory provides support to the division in the area of man-machine interfaces for remote control of robotic systems. Electronic hardware development and test tools are used to design, integrate, and test specialized peripherals for real-time telepresence applications. Specific products include the telepresence camera platform, head mounted stereo display, and general interface for displays and controls. The laboratory assets include standard electronic test equipment, work benches, video equipment, and virtual reality helmet-based test systems.

## General Facility Specifications

### ROBOTIC SENSOR INTEGRATION LABORATORY

LOCATION: Building 9NE, Technical Annex, Room 3112

POINT OF CONTACT: Chief, Automation and Robotics Division,  
Code ER, (713) 483-493

STATUS: Active

YEAR BUILT: 1991

INITIAL COST: \$80k

REPLACEMENT COST: \$80k

USE: The mission of the Robotic Sensor Integration Laboratory is to provide the division with expertise in the areas of sensor specification and in the design and development of special sensors and systems for robotic applications. The laboratory also provides for test and calibration of sensors for robotic systems as required. A database of available commercial sensors is also maintained.

DESCRIPTION: The Robotic Sensor Integration Laboratory is in process of buildup as of mid-1992. Present capabilities are

concentrated on developing machine vision systems for use on the robotic systems currently being developed in the division. In the future the capabilities will be expanded to cover other types of sensors including microwave-based motion sensors and ultrasonic phased array image sensors.

Present equipment includes the following:

- SPARC workstation with C-compiler (one)
- Ironics card cage with 68030 processor (one)
- Data Cube Image-Processing System (one)

The Precision Sound Measuring System includes the following:

- Precision Microphone B&K 4138
- Precision Microphone B&K 4135
- Precision Microphone B&K 4165
- Preamplifiers for the above

The division is currently in the process of developing a capability for the design and development of capacitance proximity sensors.

## **General Facility Specifications**

### **SPACE SYSTEMS AUTOMATED INTEGRATION AND ASSEMBLY FACILITY**

**LOCATION:** Building 9NE, sharing eastern one-third

**POINT OF CONTACT:** Chief, Automation and Robotics Division  
Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** 1991 (completion of building construction)

**INITIAL COST:** TBD

**REPLACEMENT COST:** TBD

**USE:** The Space Systems Automated Integration and Assembly Facility will provide ground test verification of on-orbit spacecraft assembly tasks that will be accomplished with docking or berthing operations and verification of spacecraft maintenance tasks that will be accomplished with robotic devices.

**DESCRIPTION:** The Space Systems Automated Integration and Assembly Facility is a large scale, closed-loop, dynamic test facility devoted to spacecraft docking and berthing, assembly, and maintenance test activities. This facility has the ability to simulate key space operating conditions and to accommodate full-scale space hardware test elements. Its initial applications will be devoted to integrated systems development and verification testing of the berthing and assembly of full-scale Space Station Freedom elements. A key step in developing realistic space assembly and maintenance processes is the

mechanical evaluation of task criteria in a ground-based, high-fidelity simulation environment that treats the component articles as a combined system. This approach requires the ability to dynamically simulate a space environment and accommodate large space elements. The ground test articles will be used in conjunction with computer simulation to produce dynamically accurate conditions to evaluate integrated operations performance. The facility consists of the high bay area with a large air-bearing floor (21.3 by 29.9 meters), special six-degrees-of-freedom dynamic simulators, a real-time simulation computer system, and a Dynamic Docking Test Facility. The facility also uses the Manipulator Development Facility and the Space Station Mobile Remote Manipulator Development Facility telerobotic arms for dynamic force inputs for certain air-bearing floor testing.

The Space Systems Automated Integration and Assembly Facility was designed to be the major facility used by the division to carry out its verification responsibility for manipulator and robotic assembly and maintenance on Space Station Freedom. The facility will integrate interfacing hardware (e.g., a docking mechanism, a berthing mechanism, or V-guides and trunnions) with real-time computer simulations of Space Station and Shuttle manipulators and robots. Ground test articles will also be used in conjunction with the computer simulations as available (and as appropriate) to produce dynamically accurate conditions required to validate integrated operations performance.

The building for this facility, with the exception of the air-bearing floor which has special design and construction considerations, was completed in FY 1991. An activation effort, which involves

relocation and procurement of test systems, is in progress to support concentrated Space Station assembly operations validation tasks beginning in FY 1993.

## **General Facility Specifications**

### **MANIPULATOR DEVELOPMENT FACILITY**

**LOCATION:** Building 9NE, sharing eastern one-third

**POINT OF CONTACT:** Chief, Automation and Robotics Division,  
Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** FY 1992 (total refurbishment of original 1970s  
build)

**INITIAL COST:** TBD

**REPLACEMENT COST:** \$10,000k

**USE:** The Manipulator Development Facility is a multipurpose  
facility that will be used in the following functions:

- Support to the flight crew training for payload handling
- Serve as a design tool for the orbiter Remote Manipulator  
System, including the complete man-machine interface
- Support to engineering development of payload, payload bay,  
and payload retention systems and visual markings
- Support to engineering development of maintenance and  
operating procedures for payload handling

**DESCRIPTION:** The refurbished Manipulator Development Facility, which is a full-scale replica of the Shuttle Remote Manipulation System, is currently being installed in Building 9NE. This refurbished facility is very similar to the current facility; however, design changes were incorporated to provide a more accurate representation of flight arm geometry and to provide an increased lift capability (i.e., maximum of 226.8 kilograms). Design of the arm maintained the highest flight fidelity consistent with the lift requirements and maintenance practices. The facility replaces most of the hardware with upgraded higher fidelity training hardware. The refurbished facility includes a higher fidelity payload bay with liners and cushions, a high-fidelity orbiter aft-cockpit crew station, new Remote Manipulation System operational panels, and a new intercom system. Key elements retained from the current facility were the orbiter vertical stabilizer, payload bay doors, radiator panels, and payload retention system. Also retained were the current closed circuit television systems (except for new color monitors) and lighting system. This refurbished facility will provide high-fidelity capability to support the training requirements and engineering studies of complex tasks that must be successfully accomplished with the Shuttle Remote Manipulation System in support of future missions and new space programs.

## **General Facility Specifications**

### **ELECTRONICS DEVELOPMENT LABORATORY**

**LOCATION:** Building 9NE Technical Annex, Rooms 2110 and 2112

**POINT OF CONTACT:** Chief, Automation and Robotics Division, Code ER, (713) 483-4931

**STATUS:** Active

**YEAR BUILT:** 1991

**INITIAL COST:** \$1,277k

**REPLACEMENT COST:** \$1,351k

**USE:** The mission of the Electronics Development Laboratory is to provide the division with expertise and services in the areas of specialized electronic devices and the design, manufacture, evaluation, test, troubleshooting, and repair of components.

**DESCRIPTION:** The Electronics Development Laboratory provides design and fabrication services for electronic hardware. The laboratory also provides support to the division in the area of man-machine interfaces for remote control of robotics systems. Electronic hardware development and test tools are used to design, integrate, and test specialized peripherals for real-time telepresence applications. Specific products include the Telepresence Camera Platform, Head-Mounted Displays, and General Interfaces for Displays and Controls.

## Chapter 7

### STRUCTURES AND MECHANICS DIVISION (ES)

#### Contents

#### Overview

FACILITY	PAGE	The Structures and Mechanics Division is responsible for the design, development, evaluation, and qualification of space vehicle structures, mechanisms, materials, thermal protection systems, and passive thermal control systems. It is also responsible for applied robotics as pertains to the design, space assembly, and maintenance of structures and mechanisms.
Atmospheric Reentry Materials and Structures Evaluation Facility .....	7-2	
Materials Technology Laboratory .....	7-6	
Atomic Oxygen Facility .....	7-8	
Chemical Analysis Laboratory .....	7-10	
Electron Microscopy Laboratory .....	7-13	The division provides state-of-the-art laboratories in which space vehicles, space vehicle modules, mechanical systems, hardware, and materials are evaluated under launch, ascent, on-orbit, entry, and landing environmental conditions.
Mechanical and Physical Testing Laboratory .....	7-16	
Metallurgical Laboratory .....	7-19	
Nondestructive Testing Laboratory .....	7-22	
Optical Analysis Laboratory .....	7-25	
Rubber Laboratory .....	7-26	The division is also responsible for programs which develop and evaluate new materials, structural concepts, mechanical concepts, and thermal concepts under appropriate space environmental conditions. It is responsible for methods of analysis and testing for space vehicle applications.
Thermal Analysis Laboratory .....	7-28	
Radiant Heating Test Facility .....	7-31	
Electro-Mechanical Systems Laboratory .....	7-35	
Small Radiant Heating Test Facility .....	7-38	
Structures Test Laboratory .....	7-39	Primary tasks include the conduct of engineering and development studies of structures, mechanisms, materials,
Vibration and Acoustic Test Facility .....	7-44	thermal protection systems, passive thermal control systems, and mechanical systems for the advancement of technology and capabilities of space vehicles. The division also provides direct technical support to the JSC program offices and other JSC organizations.
General Vibration Laboratory .....	7-47	
Modal Operations Laboratory .....	7-49	
Spacecraft Acoustic Laboratory .....	7-51	
Sonic Fatigue Laboratory .....	7-53	
Spacecraft Vibration Laboratory .....	7-55	

## General Facility Specifications

### ATMOSPHERIC REENTRY MATERIALS AND STRUCTURES EVALUATION FACILITY

LOCATION: Building 222

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$2,900k

REPLACEMENT COST: \$21,200k

USE: The Atmospheric Reentry Materials and Structures Evaluation Facility provides the capability to perform the aerothermal heating environment tests required for the screening, development, and certification of manned spacecraft thermal protection systems. This facility has been used to provide the required thermal testing support for Apollo, Shuttle, National Aerospace Plane, and Aero-Assist Flight Experiment Development by utilizing state of the art test techniques. The high-temperature environment representative of the convective heating conditions experienced by spacecraft during entry is accomplished by electrically heating the gas mixtures simulating air and expanding the flow through supersonic or hypersonic nozzles. Testing in this facility has established thermal design requirements and verified thermal performance of protection systems. Further, the facility is dedicated to sustaining engineering improvements to thermal protection systems on the

Shuttle, mission life studies, and flight anomaly investigations. Continual refurbishment and modifications to the facility will provide the capability to support the advanced thermal protection system development activities associated with new space initiatives.

DESCRIPTION: The principal components of the facility include two ten-megawatt arc heaters, test chambers with associated vacuum pumping system, steam ejectors, boiler, test gas system, water cooling system, and associated control and computer systems. At the facility two test positions which encompass 3.05 meter and 3.66 meter diameter vacuum chambers can accommodate high temperature convective heating test programs. The two test chambers share a common steam ejector vacuum pumping system with a capacity of 683 grams per second of gas flow. At each test position an arc heater is mounted to the vacuum chambers.

The arc-heater is a device for converting electrical energy into thermal energy. A continuous high-voltage, direct-current electric arc is established between a cathode and an anode at either end of a segmented column. Gases are then injected into the column and heated by the arc. The heated, high-energy gas is then expanded through a nozzle to produce a high-temperature, supersonic or hypersonic gas stream. The high-energy gas stream is used to test spacecraft thermal protection systems under simulated reentry heating environment conditions.

Gas is injected into the arc-heater through a test gas supply and control system, which has a flow of 4.54 to 683 grams per second of a simulated air mixture (oxygen and nitrogen) for a duration of .5 hour at maximum flow rate. Other gas mixtures may be accommodated. Both arc tunnels are capable of producing test gasses with total enthalpies ranging from 4.652 to 37.216 megajoules per kilogram. Both chambers can be configured with either supersonic or hypersonic conical nozzles having exit diameters ranging from .127 to 1.016 meters (in .127 meter increments) or supersonic rectangular channel nozzles, with side wall test stations. Using conical nozzles, simulation of stagnation-point convective heating rates and model impact pressures of 11.4 to 568 watts per square centimeter and 0.001 to 0.1 atmospheres, respectively, can be experienced on models of varying geometry with frontal areas of from 25.8 to 2580 square centimeters. Large models may be tested on fixed-position stanchions downstream of the nozzle exit. Smaller models may be mounted on a two-arm model insertion system in the test chambers. This system can insert and retract small test models from the gas stream and position their distance from the nozzle exit.

A supersonic rectangular channel nozzle with three test stations which accommodate test panel sizes of 20.3 by 25.4 centimeters, 30.5 by 30.5 centimeters, and 61 by 61 centimeters is available for simulating local orbiter heating and pressure environments with either laminar or turbulent boundary layers. Convective heat transfer rates of 2.27 to 51.1 watts per square centimeter and pressures of 0.01 to 0.1 atmospheres are obtainable with the channel nozzle.

Supplemental radiative heating may be obtained at the channel nozzle test stations by placing a polished "cold wall" water-

cooled panel or a "hot wall" of high-temperature refractory material in the nozzle side wall opposite a test article. Reflected energy from the polished "cold wall" or radiative energy from the "hot wall" supplements the convective heating to a test article in the channel nozzle. Using reradiation techniques, temperatures in excess of 1922 degrees Kelvin can be achieved at the channel nozzle test stations.

A unique test technique employing real-time control of the gas flow rate and arc-heater power has been developed for use with the channel nozzle. This technique simulates a reentry environment at the test station which closely matches a Shuttle orbiter reentry pressure and temperature profile for a specified body point, including flow transition from a laminar to a turbulent boundary layer. The rectangular channel nozzle has a calibration plate for each test station. Each plate is instrumented with pressure ports and heating rate sensors for use in establishing test conditions.

Control of all systems which do not interface directly with the test article is accomplished with a central facility control system, consisting of an ASEA Brown Boveri Masterpiece controller (referred to as the ABB Masterpiece) and Masterview man-machine interface. The Masterpiece controller is capable of managing over thirteen hundred analog and digital input and output channels and is used to implement both combinatorial and sequential logic control, as well as critical process control using complex regulatory elements. Integration of all control functions within a single system minimizes interfaces, and allows monitoring and cross referencing of all parameters, automatic initiation of corrective action on alarm, implementation of complex cross-system, interlocks, and automation of test sequences with a minimum of operator oversight or intervention.

The Masterview man-machine interface consists of three each of 50.8-centimeter color video display units and up to three keyboards with trackballs. Process information is displayed both graphically and numerically on the video display unit screen. Up to eighty screens may be configured with either custom process graphics, standard group, or overview displays. The operator may call up an object display of any parameter to obtain detailed information. Operator interaction with the process is accomplished by moving a cursor on the process screen to the object to be manipulated, then selecting it. After the object is selected, the desired action is implemented via selection of function keys on the keyboard. The results of the action, as well as any actions initiated by the process logic, are displayed in real time on the process screen. Thus, the video display unit screen is used both to monitor the process and to interact with it.

The Atmospheric Reentry Materials and Structures Evaluation Facility utilizes a 256-channel, computer-based data acquisition and display system for real-time measurement and display of test and facility parameters in engineering units with graph data available real time and immediately for each test. A versatile model shop is available for use by contractor personnel for test article buildup and integration into the facility's systems.

The unique reentry environment test capabilities of the JSC arc facilities which became operational in 1963 have helped develop and verify the thermal performance of every type of thermal protection system used on the manned spacecraft programs orbiter. The JSC arc facilities will continue to support the Shuttle orbiter programs and the development of new thermal protection systems for application on orbital transfer, lunar, and Mars return vehicles.

#### Laser Plasma Diagnostic Facility

The Laser Plasma Diagnostic Facility is located within the evaluation facility in Building 222. In order to size the thermal protection systems more efficiently for future spacecraft, the nonequilibrium flow conditions which exist during the high temperature reentry phases must be thoroughly understood. In trying to understand these flow conditions, the Laser Plasma Diagnostic Facility was set up to provide a nonintrusive diagnostic technique (laser induced fluorescence) to study the arc jet plasma flow which simulates spacecraft reentry conditions.

The facility consists of two class IV laser systems, one pulsed and one continuous wave. The pulsed system consists of an Nd:YAG laser which can radiate in three different wavelengths: infrared at 1.4 joules per pulse, visible at 0.7, and ultraviolet at 0.28. This Nd:YAG laser is used to pump a pulsed dye laser to generate a continuously (wavelength) tunable laser which can radiate any desirable wavelength from 215 nanometers to eleven hundred nanometers at 0.35 joules per pulse. The continuous wave laser system consists of a ring dye laser pumped by an argon ion laser. The argon ion laser generates either five watts of visible radiation or 0.4 watt of ultraviolet radiation. The ring dye laser generates a maximum of 1.5 watts of tunable radiation in the range from 265 nanometers to one thousand nanometers.

The pulsed laser system is used to collect data on the free stream and shock layer species of nitric oxide and vibrationally excited oxygen molecules. The analysis of these data will give the rotational and vibrational temperatures of the flows. This system is also used to collect resonance Doppler fluorescence data for copper in the free stream. This approach resulted in

the first nonintrusive velocity and temperature measurements for an arc heated flow field. The continuous wave system, having very low power and much smaller band width than the pulsed system, is used mostly when higher resolution data are needed. The operation of this system is more complex and requires a very high resolution spectrum analyzer to keep track of its correct longitudinal mode of operation.

DATA ACQUISITION: A new data acquisition system has been procured for the facility and is currently in the process of being installed and programmed. This system features a Hewlett Packard Model 3852 data acquisition and control unit which has the capability of being configured for a wide variety of signal inputs, data sampling rates, and control outputs. As presently configured, the system incorporates a high speed, high resolution (sixteen bit) digital voltmeter with 144 low level (10.24 volt) multiplexed input channels, and seventy (350 ohms) bridge balance multiplexed channels. In normal mode reading rates as high as five thousand samples per second may be achieved. In

high speed mode reading rates as high as 100 000 samples per second may be achieved on up to 144 channels using direct memory access to a dedicated central processor. Also configured are up to ten pulse and frequency channels and up to sixteen digital output channels.

Supervisory control of all data acquisition functions is implemented on a distributed network of four Hewlett Packard Model 382 computer workstations running Hewlett Packard Visual Engineering Environment software in a UNIX X-Windows operating environment. This software package allows rapid graphic display and revision of the test configuration and real-time color display of test data in a variety of graphic or tabular formats using windows. All test data are stored on the system disk and archived on either digital audio tape or electro-optical disk as required. Ethernet connectivity allows direct digital transfer of data to an analysis platform when requested. Post test data plots may be generated on either a laser printer (black and white) or a Hewlett Packard Paint Jet XL color printer.

## General Facility Specifications

### MATERIALS TECHNOLOGY LABORATORY

LOCATION: Building 13

POINT OF CONTACT: Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: See individual specification for each laboratory.

INITIAL COST: See individual specification for each laboratory.

REPLACEMENT COST: See individual specification for each laboratory.

USE: The Materials Technology Laboratory has the capability of performing test and evaluation of spacecraft materials by chemical analysis, optical analysis, thermal analysis, electron microscopy, flammability testing, atomic oxygen testing, elastomeric material testing, metallographic examination, nondestructive testing, and mechanical and physical testing.

DESCRIPTION: The Materials Technology Laboratory consists of nine separate laboratories specializing in the following areas:

- Atomic oxygen
- Chemical analysis
- Electron microscopy
- Mechanical and physical testing

Each of these laboratories has the capability to perform experiments and evaluations in support of NASA space programs and is described individually in detail following this general overview. The laboratories which make up the Materials Technology Laboratory and their principal functions are given in the following paragraphs.

#### Atomic Oxygen Laboratory

The primary function of this laboratory is evaluation of the effects of atomic oxygen interaction on materials, as well as the simulation of space conditions.

#### Chemical Analysis Laboratory

Primary areas of responsibility in this laboratory are chemical analysis and materials evaluation. Chemical analyses are performed on the combustion and degradation products of various polymers, and contaminants are identified. Materials are also evaluated for use in spacecraft applications. The principal function of this laboratory is the measurement of optical properties such as reflectance, transmittance, solar reflectance, and infrared emittance.

### Electron Microscopy Laboratory

The principal function of this laboratory is the support of Space Shuttle and JSC operation failure analysis through the use of scanning electron microscopy fractographs, semiquantitative chemical analysis of bulk material, and surface chemical analysis.

### Mechanical and Physical Testing Laboratory

Principal functions of this laboratory include development, evaluation, and testing of fibrous, plastic, elastomeric, and metallic materials. Nonmetallic properties which can be determined include tensile strength, elongation, compressive strength, folding endurance, burst strength, impact strength, thermal conductivity, permeability of gases, abrasion resistance, optical properties, hydrostatic resistance, and static electricity. Metallic properties which can be determined include tensile strength and fracture mechanics.

### Metallurgical Laboratory

The principal function of this laboratory is the evaluation of metals and metal failures. Evaluation of metals includes an examination of the microstructural features of metals, such as grain size, extent of corrosion, and existence of cracks or other microscopic defects which can degrade performance. Hardness tests are also performed to confirm heat treatments and detect embrittlement. Plating thicknesses, uniformity, and surface irregularities can be measured. Evaluation of metal failures includes both microscopic and macroscopic aspects in cause determination. Electron microscopy techniques are used to examine fracture surfaces for features characteristic of different failure modes.

### Nondestructive Testing Laboratory

The principal functions of this laboratory are the development and characterization of new and improved nondestructive testing techniques and program support for issues requiring nondestructive resolutions. Test capabilities include X ray, ultrasound, eddy current, conductivity, and magneto-optic imaging.

### Optical Analysis Laboratory

The principal functions of this laboratory include the testing and evaluation of the optical properties of materials used in space-related projects. A determination is made of such optical properties of materials as reflectance, transmittance, solar reflectance, infrared emittance, specular gloss, and haze.

### Rubber Laboratory

Principal functions of this laboratory are the development and evaluation of elastomeric materials.

### Thermal Analysis Laboratory

Thermal testing capabilities in this laboratory include thermal vacuum weight loss analysis, differential scanning calorimetry, dynamic mechanical analysis, thermomechanical analysis, and thermogravimetric analysis.

DATA ACQUISITION: In the Materials Technology Laboratories, data are acquired through the use of scanning electron microscopes; Fourier transform infrared spectrometer; Ultraviolet-visible spectrometer; vacuum microbalances; gas chromatographs; and X-ray fluorescence and diffraction, metallograph, atomic oxygen testing apparatus.

## General Facility Specifications ATOMIC OXYGEN FACILITY

LOCATION: Building 13, Room 259

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1988

INITIAL COST: \$15k

REPLACEMENT COST: \$20k

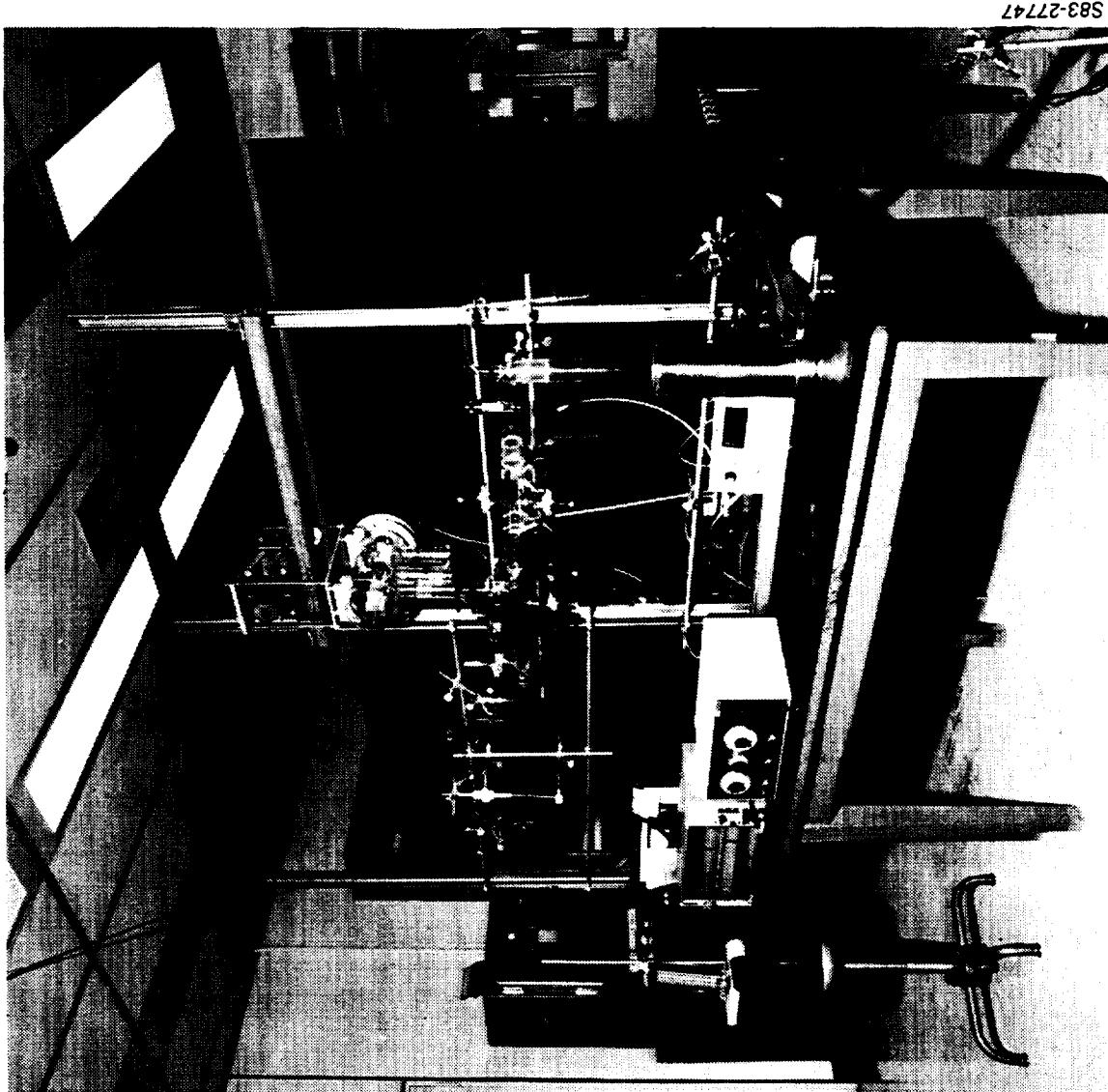
USE: The Atomic Oxygen Facility is used for simulating space environment conditions, particularly the presence of atomic oxygen and its effect on materials. Mass loss and material degradation can be measured as a function of exposure time and flux rates.

DESCRIPTION: This facility has been developed to simulate space conditions by generating atomic oxygen, which occurs in low Earth orbit. It is used to evaluate the effects of atomic oxygen interaction on materials.

The experiments are conducted in a glass vacuum tube with a Cahn electrobalance enabling mass loss measurements to be made during exposure to atomic oxygen. With one hundred percent molecular oxygen flowing into the vacuum system, ten to fifteen percent of the oxygen is excited by microwave energy, producing atomic oxygen. A characteristic "glow" is visible during titration with nitrogen tetroxide, the end point occurring when the "glow" disappears. The test apparatus will accommodate test specimens up to 2.54 centimeters square.

DATA ACQUISITION: Data are acquired with a Cahn electrobalance mass loss measurement apparatus.

**ATOMIC OXYGEN FACILITY**



## General Facility Specifications

### CHEMICAL ANALYSIS LABORATORY

LOCATION: Building 13, Rooms 255, 258, and 260

POINT OF CONTACT: Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$200k

REPLACEMENT COST: \$1,179k

USE: The Chemical Analysis Laboratory is used for chemical analysis and materials evaluations. Physical properties analysis, wet chemical analysis, ultraviolet and infrared spectrophotometric analysis, and chromatographic analysis can be performed in support of material characterization and identification.

DESCRIPTION: The primary areas of responsibility of this laboratory are chemical analysis and material evaluation. Chemical analyses of combustion and degradation products of various polymers are performed, as well as identification of contaminants. Materials are also evaluated for use in spacecraft applications. Instruments used for chemical analysis include gas chromatographies, two infrared spectrophotometers, and X-ray diffraction and fluorescence equipment. A

general wet chemistry laboratory is also available. The following equipment and processes are available in the laboratory:

- X-ray diffraction and fluorescence
- The Phillips Norelco X-ray diffraction unit: a water-cooled unit and a basic tool of X-ray diffraction and spectrography; the first block in a comprehensive array of equipment which permits the user to add standard and highly specialized compatible accessories for every type of X-ray diffraction and spectrographic study. The Phillips manual X-ray spectrometer: an instrument enabling the identification and quantitative analysis of all elements down to atomic number nine, fluorine; designed to be used in conjunction with an X-ray generator, which provides both high voltage and current for the X-ray tube and an electronic measuring panel
- Gas chromatography
- The Varian gas chromatograph, Series 3700: a modular, dual-column instrument comprised of the basic unit to which a broad range of optional modules may be added; for example, the options available permit isothermal or temperature programmed operation, packed or capillary on-column injection, and flash vaporization injection and a choice of detectors: the thermal conductivity detector, flame ionization detector, electron capture detector, and flame photometric detector
- The Tracor 150G gas chromatograph: an instrument designed for trace gas analysis, providing unequaled sensitivity and reproducibility for fixed gases, respiratory analysis, and dissolved gases or light hydrocarbons

- Infrared spectrophotometry
- The Bio Rad Fourier Transform Infrared Spectrophotometer (FTS-40): equipment providing infrared capacity, both transmission and absorbance, for material characterization and identification (basic optical bench supplemented with a microscope for infrared examination of small particles or isolated areas of a large sample)
- A 3240-SPC Computer with a seventy megabyte Winchester hard drive: an instrument providing spectrophotometer control, spectral storage, spectral manipulation and spectral reference library in support of the optical system; a computer supporting an external computer on which sample and reference spectrum can be reproduced

- The Hewlett Packard Gas Chromatograph Mass Spectrometer, coupled with a Rusk Thermal Desorption and Pyrolysis Sample Inlet: instrument that introduces standard liquid sample injection or thermally desorbed species into the chromatograph sample inlet; complete mixtures of materials such as copolymers or multicomponent liquid and solid mixtures separated into individual components for analysis by the mass spectrometer; computerized library of spectra then compared to the sample spectra for identification of the various components in the original material

DATA ACQUISITION: See above in this section.

## X-RAY DIFFRACTION AND X-RAY FLUORESCENCE AREA



## **General Facility Specifications**

### **ELECTRON MICROSCOPY LABORATORY**

**LOCATION:** Building 13, Room 146

**POINT OF CONTACT:** Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1964

**INITIAL COST:** \$100k

**REPLACEMENT COST:** \$600k

- The Amray 1400 scanning electron microscope, purchased in 1982, is the primary scanning electron microscope. It has a high-resolution capability of forty Angstroms and a low-magnification capability of five-power magnification.
- The EDAX energy dispersive spectrometer performs qualitative and semiquantitative chemical analysis. The windowless detector mode allows the detection of elements as low as carbon (atomic number six). This instrument is attached to the Amray 1400 scanning electron microscope.
- The JEOL 820 scanning electron microscope, purchased in 1989, functions as a second scanning electron microscope for low kilovoltage work. It has high resolution capability comparable to the Amray 1400.
- The Link Analytical energy dispersive spectrometer performs quantitative and qualitative microchemical analysis. The windowless detector mode can analyze for elements down to boron (atomic number five). This instrument is attached to the JEOL 820.
- The ARL 8420 X-ray fluorescence system was purchased in 1990 and provides quantitative chemical analysis of bulk liquids and solids.
- In addition to the previously mentioned equipment, there is also sample preparation equipment. The sample preparation area includes a carbon evaporator, a sputter coater and plasma etcher, and miscellaneous standards and preparation tools.

These activities are supported by the following equipment:

Failure analysis and JSC support activities encompass a wide variety of subject materials. Support ranges from material and

alloy verification and fractography to micrographic documentation of parts. One of the key analytical techniques used in failure investigation is a fractographic examination of the fracture surface. This analysis is performed at both low magnification (ten- to one-hundred-power magnification) and high magnification (greater than one-thousand-power magnification). Both macroscopic features and microscopic features characterize the failure mode. For example, macroscopic features characteristic of fatigue are "bench marks." Fine fatigue striations, also characteristic of fatigue, are microscopic features sometimes resolvable only at 10 000 times magnification or greater.

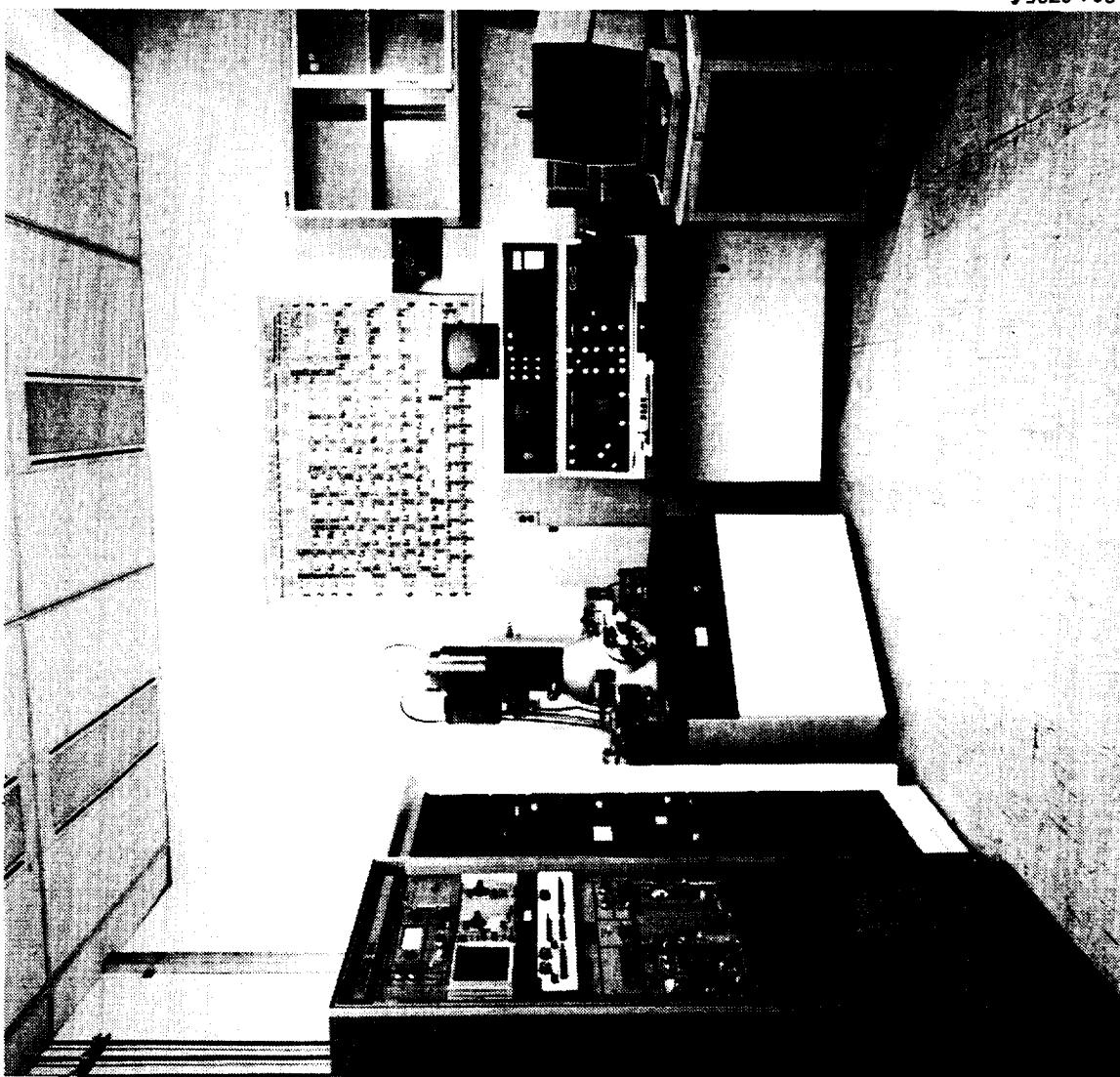
In addition to fractography support of failure analysis, an elemental chemical analysis is performed with the energy

dispersive spectrometer. Verification of materials and alloys is examined along with identification of unknown materials.

Long term research and development activities are also conducted in this laboratory. Investigations such as hydrogen migration mechanism in commercially pure titanium are being studied. A study of the hydrogen-stress environment in commercially pure titanium is being conducted in support of long-term failures in the orbiter hydraulic system swage fittings. Other research activities that employ the fractographic capabilities of the scanning electron microscope are crack propagation investigation and fractography of fracture mechanic specimens produced in the laboratory under known conditions.

DATA ACQUISITION: See above in this section.

**SCANNING ELECTRONIC MICROSCOPE WITH ATTACHED ENERGY DISPERSIVE SPECTROMETER**



## General Facility Specifications

### MECHANICAL AND PHYSICAL TESTING LABORATORY

LOCATION: Building 13, Rooms 266 and 1006

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$50k

REPLACEMENT COST: \$240k

USE: The Mechanical and Physical Testing Laboratory has capability of performing tension, compression, impact, ultraviolet degradation, and water vapor transmission testing. It is used to evaluate and test fibrous, plastic, and elastomeric materials.

DESCRIPTION: This laboratory is utilized to test and evaluate fibrous, plastic, and elastomeric materials. Some of the properties that can be determined are breaking or tensile strength, compressive strength, elongation, impact strength of plastics, water vapor transmission rate, and degradation due to ultraviolet radiation. Supporting these activities is the equipment described in the following paragraphs.

The Instron TT-C tensile tester is a valuable tool in the investigation of the physicochemical properties of materials. Tensile and compressive properties can be determined utilizing

a wide range of load cells capable of measuring loads from ten gravity full-scale to 4536 kilograms full-scale. The range of cross head speeds is from 5.08 micrometers to 50.8 centimeters per minute. The chart speeds range from 5.08 millimeters to 1.27 meters per minute.

Inasmuch as the chart of the recorder is driven independently (but synchronously), with respect to the cross head, the extension can be recorded without any additional equipment. However, if desired, this machine will accommodate the use of extensometers, compressometers, or deflectometers for the direct measurement of strain in the sample itself.

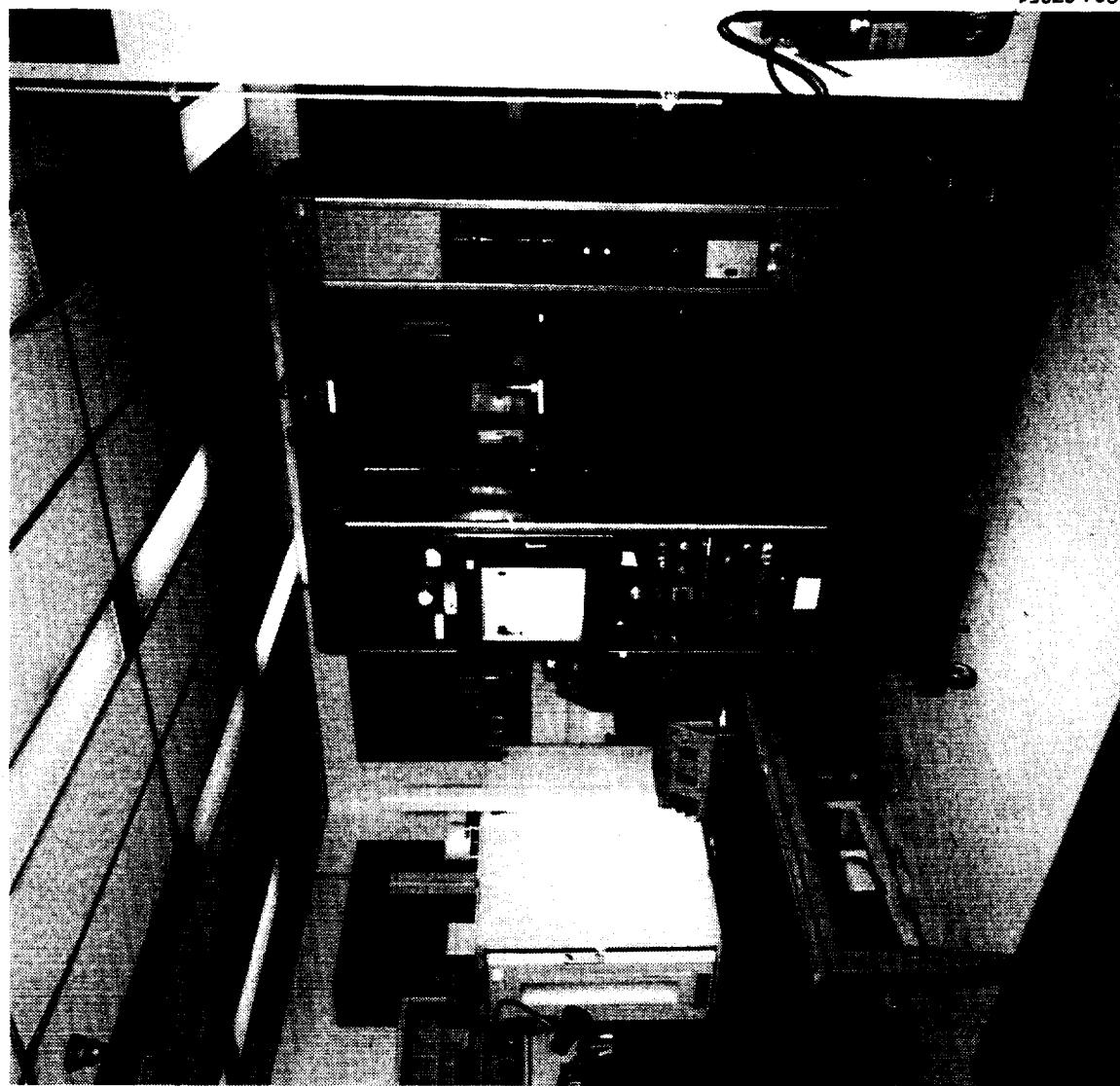
The Sunlighter II is a test console for the evaluation of sunlight effects on plastics, textiles, and protective coatings. It offers a laboratory analysis of the deteriorating effects of sunlight on a wide range of materials. One hour in the Sunlighter II equals about three days in natural sunlight.

The specimen platform is a .33-centimeter-thick aluminum disc, .4318 meter in diameter, with diffuse reflectance characteristics. An aluminum screen is mounted on the platform by a circular arrangement of nuts and bolts to provide specimen support with an air space beneath. The platform lifts from its support just as a record is removed from a phonograph turntable. This design facilitates close examination of test specimens and their removal and setup on the bench top. The effective radiant energy output is in the critical ultraviolet wavelength range between 290 and 350 microns. Since this energy is

comparatively high, rapid and accurate laboratory analysis is possible.

DATA ACQUISITION: Data are acquired through the use of an Instron TT-C tensile tester.

## TENSILE TEST AREA



## **General Facility Specifications**

### **METALLURGICAL LABORATORY**

**LOCATION:** Building 13, Room 252

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1964

**INITIAL COST:** \$50K

**REPLACEMENT COST:** \$350K

**USE:** The Metallurgical Laboratory has capability to perform metallography, light microscopy, hardness testing, and specimen preparation.

plating, and occurrence of defects or cracks. Photographic documentation of the macroscopic and microscopic appearance of the test samples is typically provided for further study and reporting purposes. A photographic darkroom facility, equipped with an enlarger, is available for processing black-and-white negatives and prints. A hardness testing capability is also available for measuring conventional Rockwell hardness as well as microhardness.

Specifically, the following equipment is available in the Metallurgical Laboratory:

- Sample preparation equipment
  - Beuhler high-speed abrasive cutoff saw: Cutting capability of soft to very hard metals, sample size to about two inches in diameter.
  - LECO low-speed diamond wafering saw: Cutting capability of most materials, producing narrow kerf, relatively small size required
  - Buehler mounting press: Capable of producing a standard, 3.18 centimeter diameter thermosetting or thermoplastic metallurgical mount
  - Six Buehler variable-speed grinding and polishing wheels (three for grinding on silicon carbide paper, typically 240 to six hundred grit, and three for polishing typically six micrometer diamond to 0.05 micrometer abrasive
  - Chemical etchants with extensive capability for etching
  - Light microscopy equipment
- DESCRIPTION:** This laboratory is used for performing metallurgical tests and examinations. The equipment available to support such tests and examinations includes sample preparation equipment, light microscopes, and associated photographic and hardness testing equipment. Testing primarily consists of metallographic sample preparation and microscopic examination. Typically, a metal sample is polished and etched to reveal its microstructure from which qualitative and quantitative information is obtained regarding the physical state and mechanical properties of the sample. Microscopic details include grain size, second phases and intermetallic compounds, nature of corrosion attack, thickness of oxide coatings or metal

- Stereo microscopes (two A. O. Smith and one Bausch and Lomb): Capable of providing binocular viewing, seven- to sixty-power continuously variable magnifications (various auxiliary lighting sources available)
- Zeiss stereomicroscope with binocular viewing and an eight- to two-hundred-power magnification range: A digital micrometer stage available for measuring specimens and features of interest
- Bausch and Lomb metallograph: Able to provide binocular viewing with fifty- to fifteen-hundred-power magnification, bright and dark field capability, polarized light capability, interference contrast, photographic capability with automatic exposure capability, photographs (typically a ten by 12.7 centimeters Polaroid), and tungsten and xenon light sources
- Zeiss axiomat metallograph with binocular viewing of forty- to 3,209-power continuous magnification range, bright and dark field capability, polarized light and interference contrast,

- photographic capability and halogen light source
- Hardness testing equipment
  - Rockwell hardness tester: Capable of performing hardness tests on the conventional C and B scales for metals and less common scales such as M and N scales for soft materials
  - Shimadzu microhardness tester: Capable of providing hardness testing of metallurgically prepared samples where microscopic identifications are required
- Photographic equipment
  - An MP4 macro camera with macroscopic photographic capability of one- to fifteen-power magnification using Polaroid ten by 12.7 centimeters film (excellent for copying Polaroid film)
  - Darkroom equipment (an enlarger, a film processing tank and trays, film dryers, and a light table)

DATA ACQUISITION: See above in this section.

## METALLURGICAL ANALYSIS AREA



## General Facility Specifications

### NONDESTRUCTIVE TESTING LABORATORY

LOCATION: Building 13, Room 163

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1964

INITIAL COST: \$50k

REPLACEMENT COST: \$241k

USE: The Nondestructive Testing Laboratory has capability to perform X-ray, ultrasonic, eddy current, penetrant, magnetic particle, acoustic emission, and visual examination of parts and materials.

DESCRIPTION: The Nondestructive Laboratory is used for performing nondestructive tests and evaluations. Equipment is available in the laboratory for performing a variety of nondestructive tests such as X-ray, penetrant, ultrasonic, eddy current, magnetic particle, acoustic emission, and visual tests. Nondestructive tests are performed for a number of reasons; the foremost reason is to determine if the item or component being examined contains defects or flaws which would compromise its use. Other common uses of nondestructive testing include the measurement of physical, mechanical, and chemical properties;

dimensional measurements; and documentation and visualization of hidden internal configurations.

Specifically, the equipment items available in the Nondestructive Testing Laboratory and a brief discussion of their functions or capabilities are given in the following list:

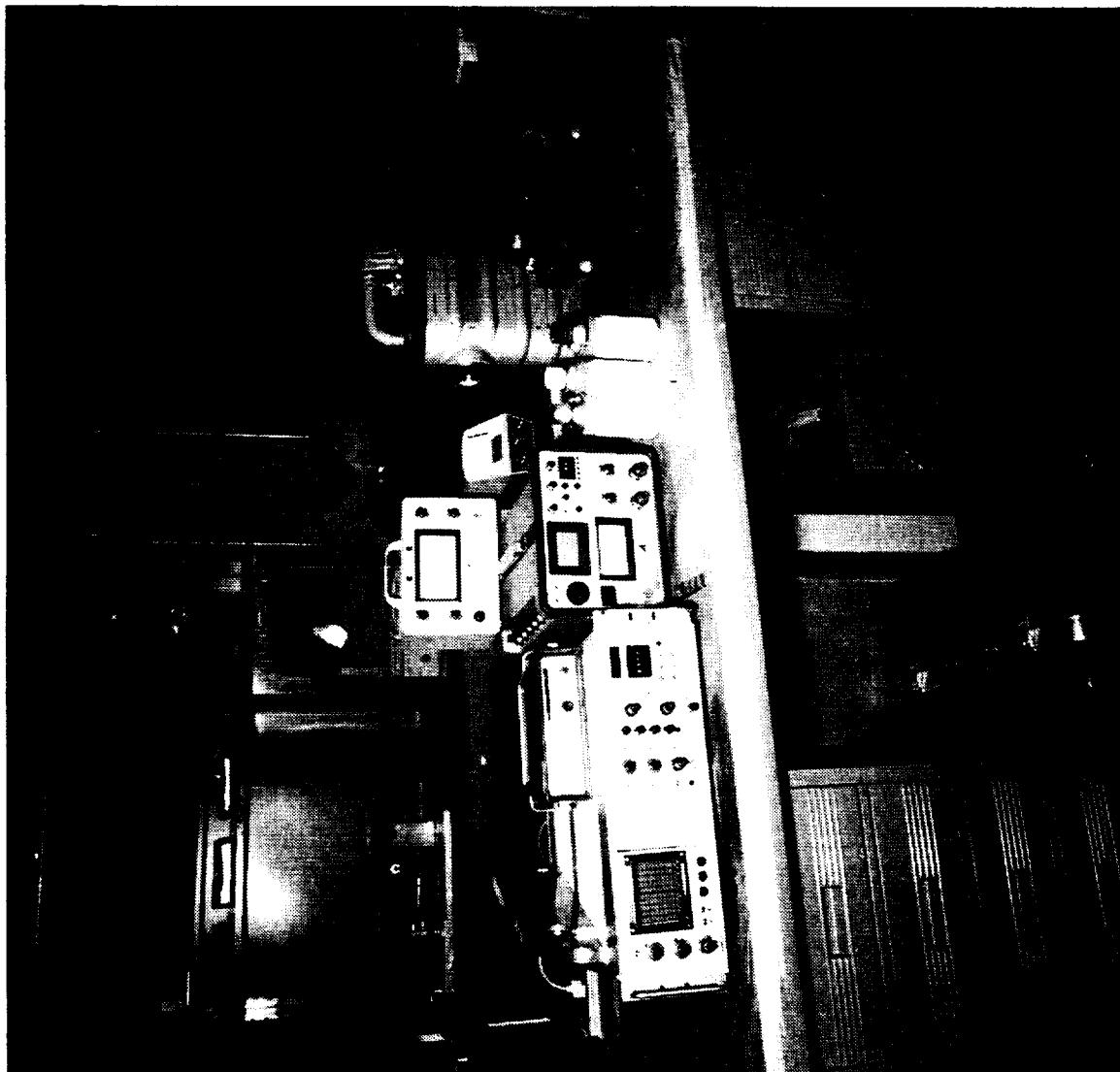
- Industrial X-ray equipment: Portable equipment producing forty to two-hundred kilovolt X-ray energy penetrates up to 1.9 centimeters of steel; measures thickness and density; and detects variations such as cracks, voids, internal configurations, and density.
- Ultrasonic equipment: Portable Nortec 140 system flaw detector and thickness gage measures thickness, sonic velocity, and attenuation properties of metals and nonmetals; its primary use is in detection of flaws such as cracks, voids, and laminations in metals and nonmetals.
- Eddy current equipment: Stavely NDT 19 and Automation EM 4300 systems measure metal thicknesses, electrical conductivity (alloy sorting, heat damage), and nonconductive coating thicknesses on conductive substrata (paint coatings); equipment detects surface connected flaws.
- Magnetic particle equipment: Portable Magnaflux unit with prods and cables and portable yoke unit detects surface and near-surface flaws in ferromagnetic metals such as iron and steel.
- Penetrant equipment: Portable kits with spray-can application detect surface flaws in metals and nonmetals using fluorescent Magnaflux ZL22A or Uresco P6F4.

- Visual equipment: Portable rigid borescopes include fiber optic light sources with a .32 centimeter diameter by 25 centimeters long rod and a ninety degree reflector and a 0.16 centimeter diameter by 15.2 centimeters long rod with a seventy degree reflector; also, stereo microscopes (two A. O. Smith and one Bausch and Lomb) include binocular viewing and continuously variable seven- to sixty-power magnification.

- Acoustic emission equipment: Portable Dunegan-Endevco 3000 series system measures acoustic activity or emissions from propagating flaws in structures during loading.

DATA ACQUISITION: See above in this section.

## NONDESTRUCTIVE TESTING LABORATORY



## **General Facility Specifications**

### **OPTICAL ANALYSIS LABORATORY**

LOCATION: Building 13, Room 258A

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$30k

REPLACEMENT COST: \$63k

USE: The Optical Analysis Laboratory has capability to  
determine optical properties including reflectance,  
transmittance, solar reflectance, infrared emittance, specular  
gloss, and haze.

DESCRIPTION: This facility possesses instrumentation that is  
capable of measuring a series of optical properties. These

properties include reflectance, transmittance, solar reflectance,  
and infrared emittance. The following testing apparatuses are  
located in JSC Building 13:

- The Beckman DK-2A reflectometer is an instrument that measures spectral reflectance or transmittance of small, flat specimens over the wavelength range of 0.25 to 2.5 micrometers. The spectral reflectance curve that is produced can be integrated to yield total solar absorptance for the specimen surface.
- The Gier Dunkle MS-251 reflectometer is a portable instrument that measures total solar reflectance of specimens "in the field." This measurement can be converted to solar absorptance.
- The Gier Dunkle DB-100 emissometer is a portable instrument that measures total infrared reflectance of specimens in the field. The value received can then be converted to infrared emittance.

DATA ACQUISITION: See above in this section.

## General Facility Specifications

### RUBBER LABORATORY

LOCATION: Building 13, Rooms 266 and 1006

POINT OF CONTACT: Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$30k

REPLACEMENT COST: \$63k

USE: The Rubber Laboratory has capability for rubber compounding and milling, rubber aging, and high-temperature, reusable surface insulation sample preparation.

DESCRIPTION: This laboratory is used for the purpose of compounding and evaluating rubber products. Some of the commercially available elastomers evaluated are natural rubber, styrene-butadiene rubber, neoprene rubber, butyl rubber, and polyisoprene rubber.

Mixing is accomplished on a Farrel rubber mill, which has 7.6-centimeter outside diameter rolls, with a working distance of fifteen centimeters between the guides. The speed of the slow roll is twenty-four revolutions per minute and the gear ratio is 1:1.4. The temperature capability of both rolls is 811 degrees Kelvin.

The press used to mold the rubber is manufactured by Pasadena Hydraulics, Inc., and is capable of exerting a pressure of 667 233 newtons on the cavity areas of the mold during the entire period of vulcanization. It has a temperature capability of 773 degrees Kelvin.

Accelerated aging tests are performed in a Scott Testers aluminum block pressure aging oven. This equipment allows for the estimation of the relative resistance of vulcanized rubber to high-temperature aging under controlled conditions. Fourteen cavities are provided.

DATA ACQUISITION: See above in this section.

## RUBBER LABORATORY



## General Facility Specifications

### THERMAL ANALYSIS LABORATORY

LOCATION: Building 13, Room 260

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: \$80k

REPLACEMENT COST: \$350k

USE: The Thermal Analysis Laboratory has capability to perform thermal vacuum weight loss analysis, differential scanning calorimetry, thermogravimetric analysis, thermomechanical analysis, and dynamic mechanical analysis of nonmetallic materials.

DESCRIPTION: This laboratory provides the capability for the thermal analysis of materials. The five types of tests accomplished in this laboratory and the equipment available for each test are given in the following paragraphs.

#### Thermal Vacuum Weight Loss Analysis

There is one Ainsworth vacuum balance system located in JSC Building 13, Room 147E. The system provides measurements of total mass loss and volatile condensable material when

subjected to environments of heat and vacuum. The following equipment is used to perform this test:

- A vacuum system capable of maintaining a vacuum of 1.3 by 10<sup>-4</sup> pascals
- A specimen holder made of stainless steel or aluminum (nominally 3.8 centimeter long and 1.25 centimeter in diameter)
- A collector plate made of a metal with a highly polished metal surface (3.8 centimeter in diameter)

#### Differential Scanning Calorimetry

The DuPont differential scanning calorimeter provides a differential analytical method in which the ordinate value at any given temperature or time is directly proportional to the differential heat flow between a sample and reference material. The integrated area of the reference material under the measured curve is directly proportional to the total differential caloric input. The system measures heats of fusion and transitions, specific heat, and calorimetric purity. Most recently, the instrument was used to determine the specific heat of a potting compound that was to be used in the design of a battery for space applications.

#### Thermomechanical Analysis

The DuPont thermomechanical analyzer measures softening temperatures, glass transition, and expansion coefficients. Most

recently, it was used to determine the effect that various degrees of moisture have on the linear coefficient of the thermal expansion of high-temperature reusable surface insulation.

#### Dynamic Mechanical Analysis

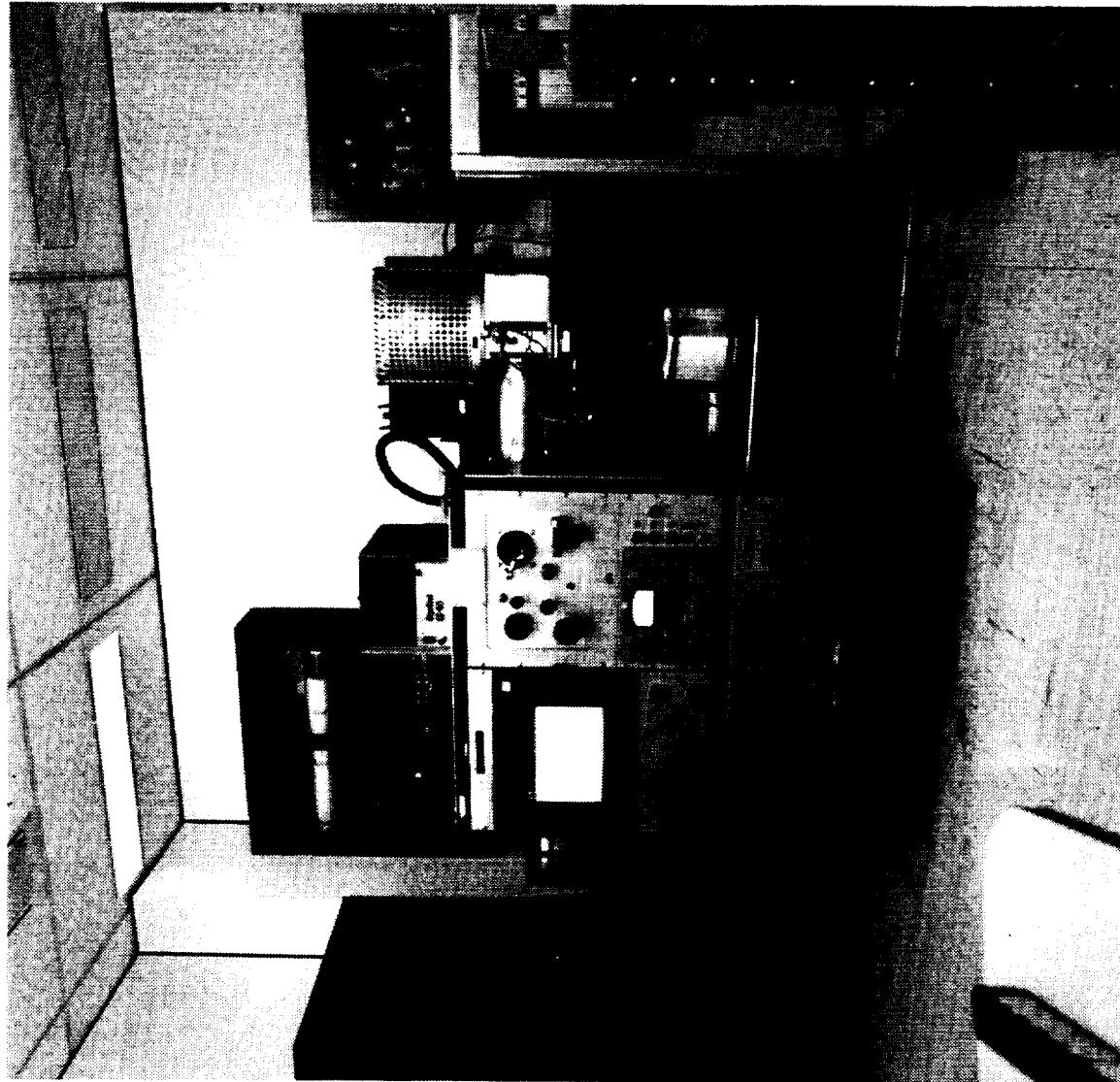
The dynamic mechanical analyzer measures the modulus, crystallinity, plasticizer effectiveness, creep, and stress relaxation of materials. Recently, this instrument was used to determine the degree of modulus change of mylar film at varying temperatures.

#### Thermogravimetric Analysis

The DuPont thermogravimetric analyzer is used to determine the thermal stability of materials by measuring changes in weight as a function of temperature and time at temperature. This instrument was used to measure the percentage weight loss of advanced flexible reusable surface insulation material at various temperatures.

DATA ACQUISITION: Data are acquired with a DuPont differential scanning calorimeter and a DuPont thermo-mechanical analyzer.

**THERMAL VACUUM WEIGHT LOSS ANALYSIS AREA**



## **General Facility Specifications**

### **RADIANT HEATING TEST FACILITY**

**LOCATION:** Building 260, High Bay

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1974

**INITIAL COST:** \$1,260K

**REPLACEMENT COST:** \$3.5M

**USE:** The Radiant Heating Test Facility has the capability of performing multizone, high-temperature, radiant-heat testing of large spacecraft thermal protection systems and associated structures in a controlled pressure environment to simulate reentry thermal profiles, thermal gradient, and pressure conditions. Test articles up to 244 by 244 centimeters in size can be tested utilizing twenty-two independent heater zones to produce thermal gradients, if required.

**DESCRIPTION:** The Radiant Heating Test Facility is used for thermal and thermostructural testing and evaluation of spacecraft thermal protection systems. The facility provides the capability of simultaneously producing temperature-time profiles, a temperature gradient, and pressure-time profile environments required to evaluate insulation-based structural composite or metallic thermal protection systems. A five megawatt power

capability and the inherent efficiency and accuracy of radiant heating permit a critical examination of comparatively large systems or structures at high temperatures, as well as rapid evaluation of new candidate thermal protection system materials.

Heating tests are normally conducted in one of the two test cells, designated R1 and R2. Test cell R1 is a 3.05 by 6.1 meter diameter by 6.1 meter long stainless steel vacuum chamber and test cell. Test cell R2 is a 2.44 meter diameter by 2.44 meter long double walled vacuum chamber with integral water cooling. Both test cells are capable of accurately simulating a wide range of ascent and entry altitude pressure profiles necessary for evaluation of insulation systems. Vacuum pumping for both test cells is provided by a dual mechanic vacuum pumping system. Either system may be used to pump either test cell, or the two pumping systems may be operated in parallel to achieve rapid pumpdown. Pump System 1 consists of a rotary vane pump and routes blower with a capacity of 1.04 cubic meters per second. A feedback control system allows control of chamber pressure in either test cell to an accuracy of plus or minus 133 pascals and provides the capability of tracking a wide range of ascent and entry pressure-time profiles.

Test cell R1 is capable of performing tests using either of two existing heating arrays. Both arrays use electrically heated graphite resistance elements and water cooled reflectors for reliable and efficient operation at temperatures to 2033 degrees kelvin. Either array is capable of operating with as many as

twenty-two independently controlled heater zones. Power for each zone is supplied by a seven hundred kilowatt single phase silicon controlled rectifier power controller package operating in the phase back mode. The 480 volt alternating current peak voltage output of the power controllers is reduced to a 120 volt alternating current peak by a four to one stepdown transformer to reduce the probability of arcing in the lower pressure test environment.

The primary heater array for test cell R1 is modular in nature and consists of the following: up to twenty-two heater modules 36.8 by 180 centimeters long, a heater support fixture, a test article fixture, and two cooling shutters which are arranged to slide between the test article and the heater bank. One of these shutters is intended to operate with water as the cooling medium to achieve entry cool down conditions, while the other is intended to operate with liquid nitrogen to simulate on-orbit cold soak prior to reentry. This heater array can be adapted to test planar or moderately curved test articles up to 1.83 by 2.44 meters in size. Additional flexibility is provided by a removable center section in each module which allows the module length to be reduced from 1.80 to 1.19 meters.

stray radiation, as well as a traverse system to move the test article.

Test cell R2 is intended primarily for materials evaluation testing using a sixty-one by sixty-one centimeter heater array. This array has been in service at JSC since 1972 and features electrically heated graphite resistance elements and a coated columbium susceptor plate to allow testing in an air oxidizing environment while maintaining a nonoxidizing nitrogen blanket around the heater elements. Test article surface temperatures as high as 1533 degrees Kelvin can be achieved with this array. Power controls for test cell R2 are identical to those used for R1 except that only a single control channel is available.

Acquisition of test data and control of the heaters and vacuum systems are performed by a MODCOMP 7845 Classic Computer with a 256-kilobyte memory and a 256-megabyte disc. Up to 256 channels of thermocouple data and sixty channels of bridge balance data may be acquired at a rate of ten samples per second per channel. Real-time data is displayed on alphanumeric video display units and posttest data may be processed in either tabular or plot format.

The secondary heater array for test cell R1 was originally fabricated specifically to test the Shuttle orbiter nose cap and is approximately hemispherical in shape with a 99.06-centimeter radius. This array presently has twenty-two independently controlled heater zones. Although it was designed for a dedicated test program, this heater is still highly serviceable and, with suitable modification, could possibly be used to test other compound curvature test articles. Ancillary equipment for this heater includes a water cooled shroud to protect the test cell walls, test equipment, and instrumentation cabling from

A new data acquisition and control system has been procured for the facility and is currently in the process of being installed and programmed. This system features a Hewlett Packard Model 3852 data acquisition and control unit which has the capability of being configured for a wide variety of signal inputs, data sampling rates, and control outputs. As presently configured the system incorporates two high speed, high resolution (sixteen bit) digital voltmeters with 384 low level (10.24 volt) multiplexed input channels, and thirty (350 ohms) bridge balance multiplexed channels. In normal mode, reading rates

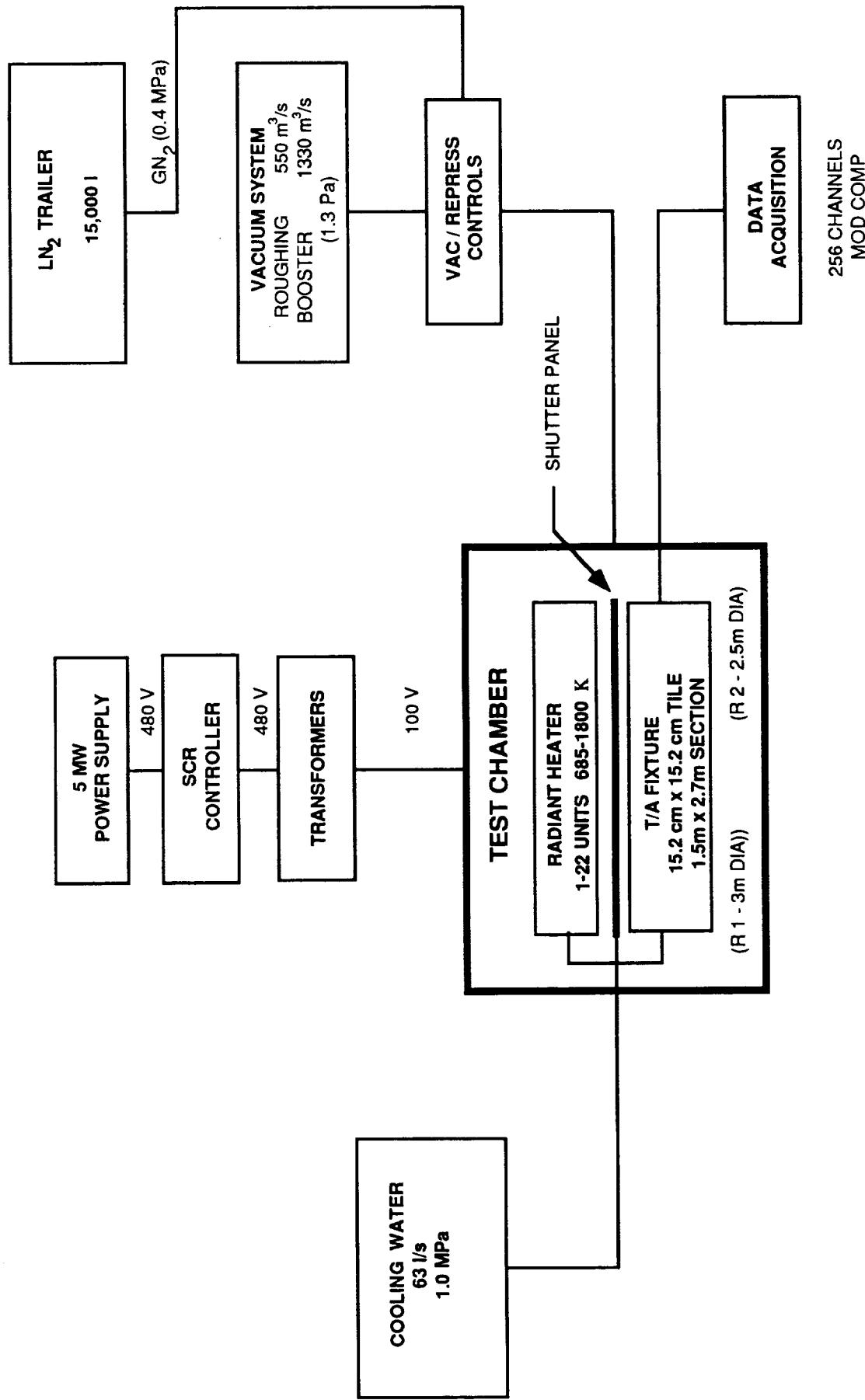
as high as ten thousand samples per second may be achieved on up to 192 channels using direct memory access to a dedicated central processor. An integrated voltmeter with sixty multiplexed solid state input channels is used to acquire data with input voltages up to three hundred volts. Also configured are twenty-eight analog output channels, ninety-six digital output channels, and ninety-six digital input channels--used primarily for facility and heater control purposes.

Supervisory control of all data acquisition and control functions is implemented on a distributed network of three Hewlett Packard Model 382 computer workstations running Hewlett Packard Visual Engineering Environment software in a UNIX and

X-Windows operating environment. This software package allows rapid graphic display and revision of the test configuration and real-time color display of test data in a variety of graphic or tabular formats using windows. All test data are stored on the system disk and archived on either digital audio tape or electro-optical disk as required. Ethernet connectivity allows direct digital transfer of data to an analysis platform when requested. Posttest data plots may be generated on either a laser printer (black and white) or a Hewlett Packard Paint Jet XL color printer.

DATA ACQUISITION: See above in this section.

## RADIANT HEATING TEST FACILITY



## **General Facility Specifications**

### **ELECTRO-MECHANICAL SYSTEMS LABORATORY**

LOCATION: Building 13, Room 2008

POINT OF CONTACT: Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1986

INITIAL COST: \$758k

REPLACEMENT COST: \$1.6M

USE: The Electro-Mechanical Systems Laboratory supports robotic and advanced mechanism research, development, testing, and evaluation. This facility has the capability to provide engineering analysis, mechanical engineering analysis, mechanical design, graphical simulation, electronic and embedded controller design, software development, systems integration, and testing for electromechanical systems. The laboratory supports the Shuttle, Space Station, and advanced programs.

DESCRIPTION: The Electro-Mechanical Systems Laboratory was organized in 1983 and is currently located on the mezzanine in the high bay area of Building 13. The laboratory area is 111 square meters with a 3.66-meter ceiling and 22.86-centimeter raised floors. There is a 3.05 by 3.35 meter removable wall section opening into the high bay to allow movement of large hardware into and out of the laboratory. The

laboratory contains isolated multiple 110- and 208-volt (three-phase) outlets and 689 476 pascals regulated air.

The laboratory supports robotic and advanced mechanism research, development, testing, and evaluation. This facility has the capability to provide engineering analysis, mechanical design and graphical simulation, electronic and embedded controller design, software development, systems integration, and testing for electromechanical systems. The laboratory supports the Shuttle, Space Station, and advanced programs.

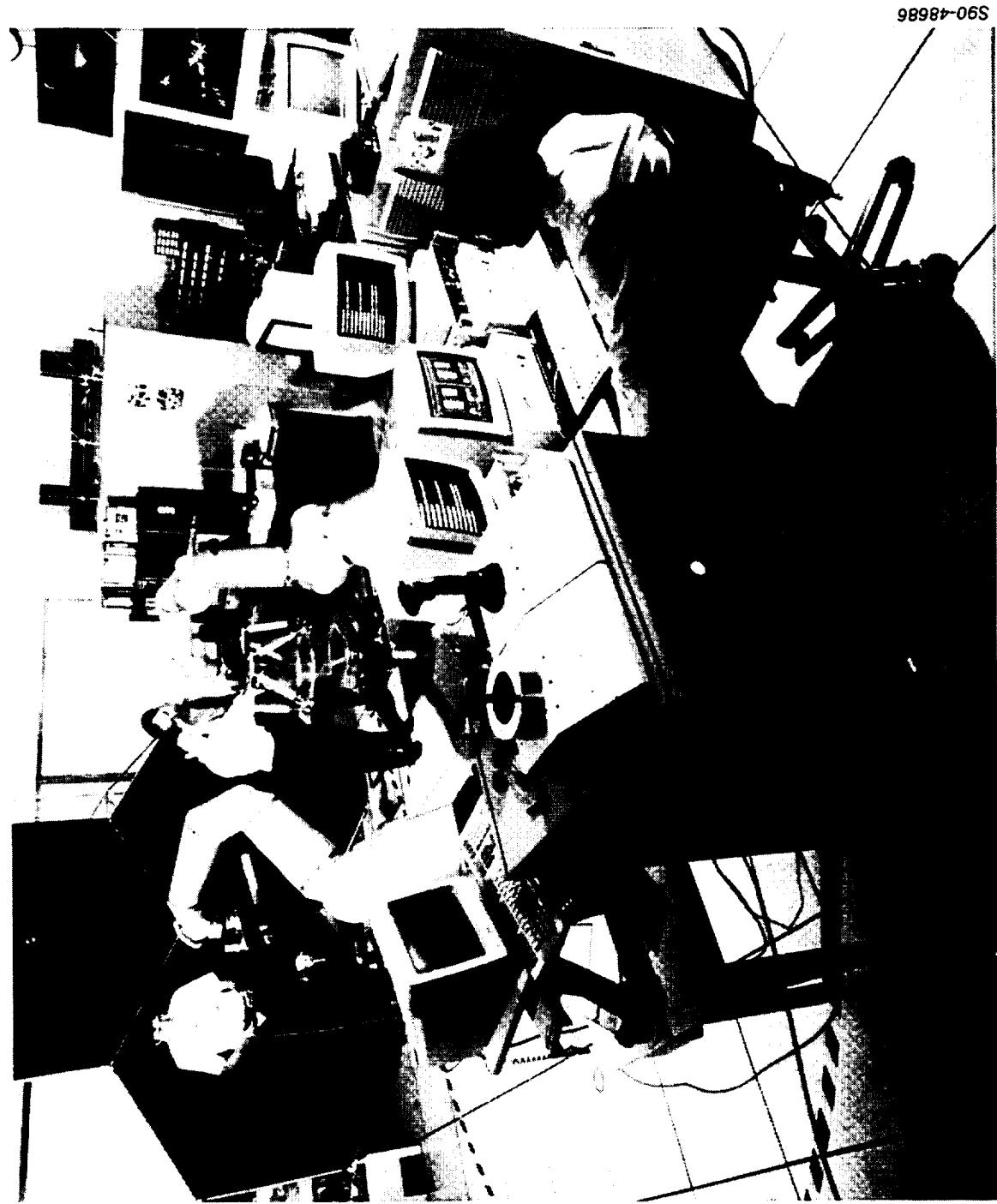
The following test and development equipment is available in the Electro-Mechanical Systems Laboratory:

- The JR3 Inc. six-axis force and torque sensor systems
- Silicon Graphics IRIS 4D210GTX graphics workstation
- Robotics Research Corporation K-1607 seven-degrees-of-freedom manipulators
- The IBM AT-compatible computers for system and software development
- Complete microcontroller development systems Intel 8051, 8096, and 80 by 86
- Intel Multibus II, iRMK (trademark for Intel Real-Time Multitasking Kernel) multitasking microcomputer system used for real-time tasks
- Cognex 2000 and 3400 Machine Vision development systems for position feedback control
- Schematic capture and printed circuit board design layout software

- Hewlett Packard Multiprogrammer high speed multichannel data acquisition system
- Electronic test equipment such as analog and digital oscilloscopes, logic analyzer, function generator, multimeter, capacitance meter, and programmable power supplies
- Dynamometer testbed for motor speed-versus-torque curves

- Attenuator and actuator testbed facility, equipped with mass simulator and load cells
  - Computer controllable linear and pulse-width modulated amplifiers
- DATA ACQUISITION: Data are acquired with a Hewlett Packard multiprogrammer, high-speed, multichannel, data acquisition system.

ELECTRO-MECHANICAL SYSTEMS LABORATORY



## General Facility Specifications

### SMALL RADIANT HEATING TEST FACILITY

LOCATION: Building 13, High Bay (southeast corner)

POINT OF CONTACT: Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1972

INITIAL COST: \$0.5M

REPLACEMENT COST: \$1.6M

USE: The Small Radiant Heating Test Facility has capability of performing environmental testing of spacecraft thermal protection systems for entry heating.

DESCRIPTION: The Small Radiant Heating Test Facility is used for the development and testing of spacecraft thermal protection systems. This facility simulates a sequence of critical environmental conditions to which thermal protection system materials are exposed: ascent heating and pressure decay, on-orbit cold soak, and entry heating and pressure recovery.

Thermal Vacuum Simulation

The heating and pressure decay associated with the ascent of any manned vehicle launch can be simulated, followed by an on-orbit cold soak simulation at an ultimate pressure of 93.3 pascals and an entry heating simulation at up to 1588 kelvin in an air environment. The test chamber, a modified boilerplate mock-up of an Apollo command module, is equipped with a graphite resistance heater which radiates to a columbium susceptor plate that has a silicide oxidation-inhibiting coating. The susceptor panel prevents oxidation of the heater elements and provides a high cross-conduction radiating surface that heats test articles more uniformly than a direct radiation system would. The heater is suspended above the test article on a set of rails and can be preheated and moved rapidly over the test article to provide a rapid rise in temperature or extracted to promote a rapid cooldown. The modest size and low manpower requirements of this facility allow for short turnaround times that are frequently required for screening or life testing of thermal protection system materials.

DATA ACQUISITION: Data are acquired with a MODCOMP computer system.

## **General Facility Specifications**

### **STRUCTURES TEST LABORATORY**

**LOCATION:** Building 13, Rooms 1000 (High Bay), 1002, 1004, 1006

**POINT OF CONTACT:** Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1964

**INITIAL COST:** \$2,268k

**REPLACEMENT COST:** \$4,828k

**USE:** The Structures Test Laboratory has capability of performing mechanical testing (tension and compression) utilizing electromechanical and servohydraulic load frames for material strength and stiffness testing of metallic and nonmetallic materials. Tests can be performed at ambient conditions or in special environmental chambers in which temperature and pressure can be varied. Large structural assemblies are tested utilizing a rigid strongback to support the test articles and a computer controlled automated load control system to apply, simultaneously, up to twelve individual loads.

**DESCRIPTION:** A Modcomp Classis computer is utilized to acquire up to 256 channels of test data at a scan rate of ten samples per second for each channel. Real-time displays of the data in engineering units are provided for fifty-six channels in

both digital format and color graphics format on cathode-ray tubes. Test data normally consist of applied load magnitudes, strains, pressures, temperatures, and deflections. Post test manipulation and plotting of the data is available.

This facility is utilized for material property testing of metallics and nonmetallics at ambient, thermal, and vacuum conditions. Industrial load test frames and test systems can test specimens up to 16.51 centimeters wide by 7.62 centimeters thick by up to 1.83 meters long with tensile loading of up to 2,668 by 10<sup>6</sup> newtons, as well as compressive loading of up to 3,559 by 10<sup>6</sup> newtons for specimens up to 0.031 square meters by 3.05 meters long.

The following servohydraulic test systems are available:

SYSTEM	QUANTITY
• Materials Test System, Inc., 2,669 by 10 <sup>9</sup> newtons test system	1
• Materials Test System, Inc., 0.979 by 10 <sup>9</sup> newtons test system	1
• Materials Test System, Inc., 0.489 by 10 <sup>9</sup> newtons test system	1
• Materials Test System, Inc., 0.245 by 10 <sup>9</sup> newtons test system	1
• Materials Test System, Inc., 0.098 by 10 <sup>9</sup> newtons test system	2

**SYSTEM****QUANTITY**

- Materials Test System, Inc., 0.044 by 10<sup>9</sup> newtons 1
- Test frame with 0.089 by 10<sup>9</sup> newton actuator

The following electromechanical test system is available:

- Instron 0.040 by 10<sup>9</sup> newtons high-speed test system
- Instron 0.195 by 10<sup>9</sup> newtons system

The following miscellaneous equipment is available:

- Riehle and SATEC static load frames (five)
- Riehle combination impact testing machine
- Vishay bending machine
- Shear fixture
- Four-point bending fixture
- Iosipescu shear fixture
- Hydrostatic proof pressure test station
- Precision air-bearing floor (4.88 by 4.88 meters)

A vertical structural steel strongback 6.5 meters wide by 1.52 meters thick by 6.1 meters high can accommodate special test setups utilizing a large assortment of industrial hydraulic actuators for load testing with a twelve-channel Materials Test System servohydraulic load control system for static or cyclic fatigue testing. The strongback has vertical T-slots on the east and west faces capable of accommodating 2.235-centimeter diameter T-slot bolts on 7.62-centimeter centers. The strongback also has nine deep floor beams flush with the floor extending 8.51 meters to the east and west. The floor beams are on 76.2-centimeter centers and are fitted with 15.24 by 15.24 centimeter hole patterns tapped for .88 to 14 UNF-2B by 2.54-

- centimeter-deep threads to permit bolting of floor plates for test fixtures. Steel test fixtures can also be welded to the floor beams if the existing hole patterns are not adequate for the test fixture floor plates.

Detailed features of this equipment including a description of data acquisition equipment available are given in the following breakdown:

- Twelve-channel automated load control system with
  - Two 24 948-kilogram actuators with +/- 7.6-centimeter strokes
  - Two 9979-kilogram actuators with +/- 7.6-centimeter strokes
  - Two 4990-kilogram actuators with +/- 7.6-centimeter strokes
  - Four 2268-kilogram actuators with +/- 7.6-centimeter strokes
  - Two 1361-kilogram actuators with +/- 7.6-centimeter strokes
- Matching dual-bridge load cells and Materials Test System "load limiters" for each actuator
- Control console that can operate all channels proportionally or individually, with a function generator capable of ramp or sine wave loading for static incremental loading or cyclic fatigue loading
- Materials Test System 2.669 by 109 newtons servohydraulic test system
  - Space between columns: 1.22 meters
  - Space between compression platens (maximum): 3.05 meters
  - Maximum of 1.83 meters between self-aligning hydraulic grips

- Maximum 7.62-centimeter-thick by 16.51-centimeter-wide tensile specimen
    - Tensile load: 272 155 kilograms
    - Compressive load: 362 874 kilograms
    - Cyclic rate of zero to 0.16 hertz (dependent upon stroke)
    - Maximum ram stroke: 25.4 centimeters
  - Materials Test System 0.979 by 109 newtons servohydraulic test system
    - System size: 0.979 by 109 newtons
    - Stroke: 25.4 centimeters
    - Specimen length: 205.74 and 91.44 centimeters
    - Space between columns: 71.12 centimeters
    - No grips
  - Materials Test System 0.489 by 109 newtons servohydraulic load system
    - Space between columns: 60.96 centimeters
    - Maximum of 160 centimeters between self-aligning hydraulic grips
    - Maximum 1.9-centimeter-thick by 7.62-centimeter-wide tensile specimen
    - Cyclic rate of zero to six hertz (dependent upon stroke)
    - Maximum ram stroke: 10.16 centimeters
    - Capability for being fitted with a 0.098 by 10<sup>9</sup> newtons ram that has a cyclic rate of zero to one-hundred hertz (dependent upon stroke)
  - Materials Test System 0.245 by 106 newtons servohydraulic load system
    - Space between columns: 76.2 centimeters
    - Maximum of 182.88 centimeters between self-aligning hydraulic grips
    - Maximum 1.9-centimeter-thick by 10.16-centimeter-wide tensile specimen
- Cyclic rate of zero to ninety-six hertz (dependent upon stroke)
    - Maximum ram stroke: 10.16 centimeters
    - Capability for being fitted with a 0.098 by 10<sup>9</sup> newtons ram that has a cyclic rate of zero to one-hundred hertz (dependent upon stroke)
  - Servohydraulic load frame (CGS) 0.445 by 10<sup>9</sup> newtons
    - Fitted with 0.089 by 10<sup>9</sup> newtons actuator
    - Space between columns: 50.8 centimeters
    - Maximum of 182.88 centimeters between self-aligning hydraulic grips
    - Maximum 1.27-centimeter-thick by 4.45-centimeter-wide tensile specimen
    - Maximum ram stroke: 10.16 centimeters
      - Cyclic rate of zero to ninety hertz (dependent upon stroke)
  - Materials Test System 0.098 by 10<sup>9</sup> newtons servohydraulic test system (two)
    - Space between columns: 55.88 centimeters
    - Crosshead travel: 152.4 centimeters
    - Presently fitted with a 0.022 by 10<sup>9</sup> newtons actuator used for high frequency cyclic load testing to determine crack growth
  - Instron 0.107 by 10<sup>9</sup> newtons high-speed electromechanical test system
    - Space between columns: 55.88 centimeters
    - Maximum 139.7 centimeters crosshead travel
    - Loading rates of 5.08 or 50.08 centimeters per minute
    - Capability for being fitted with a thermal vacuum chamber (vacuum to 13.33 by 10<sup>-6</sup> pascals and temperature to 1255 degrees kelvin or vacuum to 13.33 by 10<sup>-8</sup> pascals and temperature of 366 to 478 degrees kelvin)

- Capability for using an environmental chamber with a temperature capability of minus two hundred to plus 589 degrees kelvin
  - Static load frames
    - Maximum 25.4- by 25.4-centimeter-cross section and 76.2-centimeter maximum length specimen size
    - Maximum load of 5443 kilograms
    - Maximum temperature of 1255 degrees kelvin
  - Riehle combination impact testing machine
    - Capability for Izod, Charpy, and tension impact testing in accordance with American Society for Testing Materials Specification E-23
    - Impact capacity of 41 to 325 joules at a velocity of 3.44 or 4.88 meters per second
  - Vishay bending machine
    - Variable speed plate bending with constant displacement
    - Stroke adjustment from zero to 7.62 centimeters
    - Speed range of sixty to 1,750 cycles per minute
    - Maximum force capacity of 45.4 kilograms
  - Four-point bending fixture
    - Maximum 30.48-centimeters length by 10.16-centimeter width by 1.905-centimeter thickness specimen size
    - Maximum load of 5443 kilograms
    - Maximum stroke to 10.16 centimeters
  - Hydrostatic proof pressure station
    - Maximum cyclic rate of five hertz (dependent upon stroke)
    - Maximum pressure of 0.082 by  $10^9$  pascals gauge with superpressure fittings and 0.069 by  $10^9$  pascals gauge with pipe fittings
    - Maximum 60.96-centimeter width by 121.92-centimeter height by 152.4-centimeter length specimen size
    - Water ram: 245.8 by  $10^{-5}$  cubic meter
- Cyclic rate dependent upon stroke required for test pressure
  - Miscellaneous equipment
    - Inventory of double acting hydraulic actuators from 3.81-centimeter to 30.48-centimeter bore with stroke capacities from 5.08 to 121.92 centimeters and a tension load capacity of 121 575 kilograms
    - Inventory of single-bridge and dual-bridge load cells with a maximum capacity of 22.68 to 272 155 kilograms
    - Inventory of pressure transducers with capacities of zero to 103 421 pascals absolute to zero to 17.236 by  $10^6$  pascals absolute, and zero to 103 421 pascals gauge to zero to 137.895 by  $10^6$  pascals gauge
    - Inventory of linear variable displacement transformers with ranges of +/- 1.27 millimeters to +/- 7.62 centimeters
    - Inventory of dial indicators with a ranges of +/- .381 millimeters to +/- 25.4 centimeters
    - Workshop with drill presses, grinders, sanders, a bandsaw and a power backsaw, and gas and arc welding equipment for minor test fixture fabrication
    - Tool crib which maintains a supply of consumable items to support the laboratory and and inventory of load cells, transducers, linear variable displacement transformers dial indicators, and other precision measuring devices
      - Data acquisition equipment
      - MODCOMP 256-channel classic computer with tape and disc storage
        - Hewlett Packard 385A
        - Sixty-four channels
        - One hundred thousand channels per second
        - Portable
        - One 48.26-centimeter color monitor
        - Sixteen track tape

- Two 8.89-centimeter floppy drives
  - One hundred fifty-two megabyte hard disk
  - Five color cathode-ray tube displays
  - Line printers
  - Plotters
  - Fluke forty-channel data loggers
  - Strip chart recorders
  - X Y' plotters
  - Oscillographs
  - Direct readout indicators (e.g., dial indicators and load-all readouts)
  - Two hundred sixty channels of transducer signal conditioning
  - Vishay digital strain indicators (five)
  - Real-time data acquisition capabilities
    - Continuous recording of up to 256 data channels at a rate of ten samples per second per channel
    - Cathode-ray tube display of up to fifty-six data channels in engineering units and ratio format with one second data update
    - Real-time graphics display up to sixty channels of data
    - Tabular data printout of up to 256 selected data channels in engineering units on operator command
    - Time history plots of up to ten selected data channels on a ten-inch wide grid
    - Two modes of abort limit checking for up to 256 data channels
    - Abort and stop load application if any data channel automatic abort limit is reached or exceeded
  - Display of yellow warning and red abort conditions on the cathode-ray tube displays
  - Tabular printout of instantaneous engineering unit data values at the time of an abort
  - Posttest data reduction capabilities
    - Tabular printout of any or all parameters in engineering units versus time
    - Tabular printout of the test maximum and minimum engineering units encountered for each recorded parameter
    - Tabular printout of any or all parameters in engineering units at a preselected cycle number, event, or time for cycling tests
    - Capability for plotting individual data channels in engineering units versus time, percent load, or other selected parameters up to six traces on the Y-axis on a 21.59 by 27.94 centimeter plot
    - Posttest time history plots of any channel with its reference and commanded load on a 25.4-centimeter wide grid
    - Capability for processing and tabulating, or plotting in any single type of format, all 256 data channels in a given test time slice within fifteen hours of data reduction initiation
- DATA ACQUISITION: Data are acquired with a MODCOMP Classic computer with tape, disc storage, and associated peripherals. A portable Hewlett Packard system is also available.

## General Facility Specifications

### VIBRATION AND ACOUSTIC TEST FACILITY

LOCATION: Building 49

POINT OF CONTACT: Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

STATUS: Active

YEAR BUILT: 1965

INITIAL COST: Not available

REPLACEMENT COST: Not available

USE: The Vibration and Acoustic Test Facility laboratories have capability to perform the wide range of tests needed to evaluate all aspects of acoustic, vibration, structural dynamic, and shock parameters associated with powered flight of aerospace vehicles. The laboratories also provide capability to perform development, qualification, and acceptance testing of aerospace and nonaerospace equipment which is subjected to high-intensity acoustic noise, vibration, and shock environments.

DESCRIPTION: The laboratories contained in the Vibration and Acoustic Test Facility provide the capabilities to perform the wide range of tests needed to evaluate all aspects of acoustic, vibration, structural dynamic, and shock problems associated with the powered flight of aerospace vehicles. In addition, these labs provide the capabilities for development, qualification, and acceptance testing, not only of aerospace vehicles and

equipment, but also nonaerospace equipment which is subjected to high-intensity acoustic noise, vibration, and shock environments. The following individual laboratories make up the facility:

- General Vibration Laboratory
- Modal Operations Laboratory
- Sonic Fatigue Laboratory
- Spacecraft Acoustic Laboratory
- Spacecraft Vibration Laboratory

Each of these laboratories is described separately following the Vibration and Acoustic Test Facility overview presented here.

The JSC test team works in cooperation with visiting users during every phase of a test program to optimize test support and ensure accomplishment of test objectives. Computerized data systems support test instrumentation requirements in all laboratories. Existing programs and hardware can be adapted to most tests, and the JSC test team has extensive experience in devising special instrumentation techniques to accommodate unique test requirements. The facility was used to provide extensive dynamic structural test support (i.e., vibration, acoustic, and modal) for Apollo, Skylab, and Shuttle Orbiter certification utilizing state-of-the-art techniques. The facility, which has unsurpassed low-frequency acoustic test capabilities, provides unparalleled features for accomplishing acoustically and mechanically induced vibration testing and empirical modal analysis within one building. Laboratory arrangements and test

support systems are equally well suited for components or large assemblies.

Test operations in the Vibration and Acoustic Test Facility are supported by a variety of data, instrumentation, communication, photographic, and controlled power amplifier systems. These systems and capabilities are briefly described in the following paragraphs.

#### Computerized Data and Control Systems

An automated data acquisition, data processing, and test control system which employs medium-sized computers for on-line computations and system control is used to support test operations in the facility. This system accepts raw analog data from test measurements or recorded information from analog tapes, converts the information into digital format, performs prescribed computations, adjusts peripheral test environment control devices, and outputs processed information in the form of digital printouts and plots with parameter descriptions.

During a test, limited real-time information in raw form can be displayed on oscilloscopes, and meters paralleled with the data recording system. After testing, additional raw data can be reproduced from the analog tapes and displayed on oscillographs, or a limited quantity can be processed using digital tape processing equipment. Thirty one-third octave plots per hour and six power, spectral-density plots per hour can be produced. In addition, special processing (e.g., amplitude versus frequency, phase versus frequency, and correlation function) can be accommodated on a limited basis.

#### Data Monitoring and Processing

Remote audio communications between Vibration and Acoustic Test Facility test duty station personnel may employ a hard-line intercommunications system. The hard-line intercommunications system has a capability for eleven separate channels. Trunk lines are installed throughout the facility complex as are many connection and channel selection stations. Additional stations can be installed at unique locations required by laboratory users. Lightweight headsets are used by most operators.

#### High-Frequency Data Acquisition System

The five laboratories in the facility are supported by a central analog data acquisition system in the main control room. This acquisition system, which records data on magnetic tape, has a capacity of 312 channels of zero- to 2.5-kilohertz data and thirty-six channels of zero- to twenty-kilohertz data. The channels can be allocated to one laboratory or distributed to simultaneously support all five laboratories. Standard fourteen-track analog tape recorders are the primary systems used for recording raw data. Three recorders are operated in the frequency-modulation mode from zero to twenty kilohertz. Thirty-six channels are

**Closed-Circuit Television**

A central video system provides remote surveillance through a closed-circuit television network of eight black-and-white cameras, 71.12- and 35.56-centimeter console monitors, and fourteen 43.18-centimeter overhead monitors. A remote pan and tilt and zoom capability is available for all cameras. The camera cabling runs to all laboratories. Most of the monitors, together with a message writer system and video tape recording equipment, are located in the main control room.

**Photographic Equipment**

The facility complex does not maintain and operate photographic equipment. However, the JSC Image Sciences Division can provide equipment and personnel to meet the broad spectrum of still, normal-speed, and high-speed photography requirements both inside and outside facility test cells.

DATA ACQUISITION: See above in this section.

## **General Facility Specifications**

### **GENERAL VIBRATION LABORATORY**

**LOCATION:** Building 49

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** \$1,868k

**REPLACEMENT COST:** \$6,000k

**USE:** The General Vibration Laboratory is designed for testing structural components and systems and has a variety of systems for providing vertical and horizontal mechanical excitation. All shaker and thruster systems are mounted on seismic masses to preclude transmission of vibration to other laboratories.

**DESCRIPTION:** This laboratory is designed for the testing of structural components and systems, such as qualification testing of the Shuttle orbital maneuvering engine and development testing of storage lockers located in the Shuttle crew compartment. This laboratory has a wide variety of systems for providing vertical and horizontal mechanical excitation.

A vibration test cell located in this laboratory provides an acoustic enclosure for the shaker and thruster systems. Double

doors are provided for test cell access; for large articles, access is through removable ceiling panels. The 133 447-pascal shaker is surrounded by a work platform for easy access. All shaker and thruster systems are mounted on seismic masses to preclude the transmission of vibration to other laboratories.

The high bay of the General Vibration Laboratory is also used to support pretest preparation of spacecraft modules. The laboratory is approximately 19.8 meters wide by 35.1 meters long with a clear working height of 9.1 meters. An overhead crane has separate 4500 and eighteen thousand kilogram hooks, steel tie-down plates mounted in the laboratory floor, cable trenches, and pneumatic and electrical utility systems. Other support facilities are located throughout the laboratory. An 8.5- by 4.3-meter control room is adjacent to the seismic mass area with instrumentation support for data acquisition provided from the main control room. Vibration and strain measurement requirements for up to ninety-nine channels can be accommodated. Adjacent to the laboratory's control room is a power amplifier room which houses two solid-state power amplifiers that provide power to all acoustic air modulators and most vibration shakers and thrusters. A 144-kilovoltampere power amplifier (expandable to 192 kilovoltampères) is used to drive shakers and thrusters. Shaker systems are monitored automatically through an ancillary control console. Test control is provided by a minicomputer which includes programs for random, sine, and shock control. Unique vibration and shock

test requirements can be met with special configurations of shakers, thrusters, hydrostatic bearings, and air springs.

#### General Characteristics

- Laboratory dimensions: 18.3 by 35.1 by 9.1 meters
- Laboratory access: sliding door, 7.1 meters wide by 91.4 meters high
- Noise enclosure: 8.5 by 10.4 by 4.6 meters
- Enclosure access
  - Ceiling: 2.4 by 2.4 meters removable panels (five)
  - Doors: standard-sized double doors
- Hoist: bridge crane with separate 4536 and 18 144 kilogram hooks

#### Seismic Mass

- Size: 5.2 by 3.0 by 1.8 meters deep (concrete)
- Suspension: bellows air springs underneath
- Resonance frequency: 0.8 hertz
- Quantity: two

#### Vibration System

- Vertical, single shaker
  - Force output: 133 440 newtons, continuous
  - Frequency range: five to two thousand hertz

DATA ACQUISITION: See the Vibration and Acoustic Test Facility overview.

## **General Facility Specifications**

### **MODAL OPERATIONS LABORATORY**

**LOCATION:** Building 49

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1966

**INITIAL COST:** \$100k

**REPLACEMENT COST:** \$2,000k

**DESCRIPTION:** The Modal Operations Laboratory has demonstrated an ability to accurately determine the dynamic characteristics of complex structures and provide an understanding of structural dynamic behavior. Derivation of an empirically based modal model for comparison to and correction of analytically derived finite element modal models is a routine task. Modal Operations Laboratory personnel have consistently demonstrated an ability to locate critical areas of structure prior to beginning environmental tests. Comparison of preenvironmental test modal data to postenvironmental test modal data has been used to identify significant structural damage not detected by conventional X-ray and ultrasonic inspection methods.

**USE:** The Modal Operations Laboratory has capability to accurately characterize the dynamic characteristics of complex structures. Modal analysis results in identification of natural modes and frequencies of structures. The modes are characteristic shapes associated with particular resonance frequencies and are inherent in all structures. Mode shapes and frequencies are dependent upon mass and stiffness properties of the complete structural system. A modal survey allows the modes to be visualized and described mathematically by identifying each resonant frequency and its associated damping, mass, and global flexing pattern or mode shape. Modal analysis is helpful in locating and correcting structural deficiencies, such as dynamic weaknesses or lightly damped modes, which are major causes of vibration, noise, and fatigue in mechanical equipment.

Modal analysis results in identification of natural modes and frequencies of structures. The modes are characteristic shapes associated with particular resonance frequencies and are inherent in all structures. The shapes and frequencies are dependent upon mass and stiffness properties of the complete structural system. A modal survey allows the modes to be visualized and described mathematically by identifying each resonant frequency and its associated damping, mass, and global flexing pattern or mode shape. The analysis is extremely helpful in locating and correcting structural problems, such as dynamic weaknesses or lightly damped modes, which are major causes of vibration, noise, and fatigue in mechanical equipment.

Data acquisition is accomplished by exciting the structure with an impulse hammer or shaker and measuring both input force and output structural response. From this information a computer-based program computes four functions: input spectrum, output spectrum, frequency response, and coherence. The frequency response function is used in the calculation of modal parameters. The coherence function provides a means of checking measurement accuracy so that unacceptable data can be re-collected. Other safety features include automatic overload protection and the ability to preview signals before each measurement is made. All frequency response functions are stored with full annotation and an optional reference label.

Fast data collection is accomplished with a high resolution, auto ranging, twenty-four channel, analog-to-digital processor. The use of this processor is extremely important in timely accomplishment of modal test objectives since data collection is normally the most time-consuming portion of a survey.

Frequency response functions between the input forcing position and the twenty-three response positions can be collected simultaneously, thereby saving expensive engineering time. For most structures, a complete definition of structural modes can

be obtained from triaxial response measurements produced by a uniaxial forcing function. The acquisition of 225 functions per working day is considered routine.

A modal model is constructed by operating upon the measured frequency response functions. Modal shape coefficients can be obtained by the simple extraction of the quadrature component of the frequency response or by the utilization of time domain or frequency domain curve-fitting algorithms. The software being used within the Vibration and Acoustic Test Facility is very flexible, allowing many options of data displays, formats, frequency windows, modal parameter estimations, and automation and user interactions in the analysis process.

Arithmetic operations can be performed on the collected frequency response functions to rescale or manipulate the data as required. Complete documentation for the finished survey is recorded for easy access to any of the geometry, function, parameter, or modal shape information.

DATA ACQUISITION: Data are acquired through a high resolution, auto ranging, twenty-four channel, analog-to-digital processor.

## **General Facility Specifications**

### **SPACECRAFT ACOUSTIC LABORATORY**

**LOCATION:** Building 49

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1966

**INITIAL COST:** \$3,054k

**REPLACEMENT COST:** \$9,000k

**USE:** The Spacecraft Acoustic Laboratory has capability to simulate induced launch and aerodynamic noise environments of large spacecraft structures. The laboratory is normally configured for reverberant acoustic testing; however, it also has a low-frequency, high-force vibration test capability. The laboratory is equipped to perform the following types of acoustic tests: complete evaluation of integrated spacecraft, including electrical, mechanical, and structural systems; tests involving crew participation; tests of individual modules; and tests of spacecraft modules without the internal system installed.

**DESCRIPTION:** This laboratory can be used to simulate induced launch and aerodynamic noise environments of large spacecraft structures. Although the acoustic laboratory is configured primarily for acoustic testing, it also has a low-

frequency, high-force vibration test capability. The laboratory is equipped to perform the following types of acoustic tests:

- Complete evaluations of integrated spacecraft vehicles including electrical, mechanical, and structural systems
- Tests involving crew participation
- Tests of individual modules
- Tests of spacecraft modules without the internal system installed

Testing is performed primarily in a 12 820 square meters reverberant chamber with accommodations for twenty-five horns in the walls and ceiling. The largest of two acoustic chambers available in the Vibration and Acoustic Test Facility, the reverberant chamber is equipped with an adjustable ceiling which can be positioned at either a 9.75- or 22.86-meter elevation. An inventory of twenty 30 000-acoustic-watt and eighteen 10 000-acoustic-watt noise generators is available to drive the horns. Noise generators are driven by twenty-four solid-state power amplifiers, each having an output capability of four kilovoltamperes. Noise generators operate by modulating a compressed air stream that is provided by three compressors and distributed to the air modulators with an elaborate manifold. The compressors can be operated individually or combined to provide a continuous total flow of 1529.3 cubic meters per minute at approximately 206 800 newtons per square meter gauge pressure.

With the ceiling at the 22.86-meter elevation, the noise generators can produce diffuse acoustic fields with sound pressure levels up to 162 decibels (re: twenty micronewtions per square meter). Test articles up to 9.14 meters in diameter, 19.81 meters in length, and 60 039 kilograms in weight can be accommodated. By lowering the table ceiling, a 5574 square meters chamber is formed which enables testing to 165 decibels. In this lower ceiling configuration, the vertical height of the test article must be adjusted accordingly. A 33 566-kilogram fixed hoist and a 13 608-kilogram bridge crane are installed above the chamber ceiling.

An automatic (digital-computer-based) closed-loop control system controls acoustic test levels and frequency distribution. Instrumentation systems can record 348 channels of acoustic, vibration, and strain data. Test conditions are programmed from the main control room by using an automatic spectral control system which uses a computer for digital processing and control instruction generation. The system adjusts the spectral sound levels in one-third-octave band widths to preestablished levels and displays the actual and programmed values. In an emergency the main control room can vent compressors one and two to ambient atmosphere, thus removing compressed air to the modulators.

#### General Characteristics

- Chamber dimensions
  - Ceiling at 22.86-meter elevation: 11.89 by 14.33 by 22.86 meters
  - Ceiling at 9.75-meter elevation: 11.89 by 14.33 by 9.75 meters

- Test article dimensions: ten-meter diameter by 19.8 meters maximum
- Test article weight: 68 039 kilograms concentric load
- Access: Removable wall, ten meters wide by 8.84 meters high
- Hoist: 33 566 kilograms fixed hoist and 13 608 kilograms bridge crane
- Elevator: Automatic 1814 kilograms capacity compressed air systems
- Compressor 1: 764.6 cubic meters per minute at 206 843 pascals gauge
- Compressor 2: 84.95 cubic meters per minute at 206 843 pascals gauge
- Compressor 3: 84.95 cubic meters per minute at 206 843 pascals gauge

#### Acoustic System

- Acoustic powers
  - 510 000 acoustic watts (< 500 hertz)
  - 180 000 acoustic watts (< 1600 hertz)
  - Horns (lower cutoff): 20, 25, 40, 50, 100, 150, 250, and 400 hertz
  - Chamber level (overall)
    - Ceiling at 9.75 meters: 165 decibels (twenty micronewtons per square meter)
    - Ceiling at 22.86 meters: 162 decibels (twenty micro-newtons per square meter)

DATA ACQUISITION: Data are acquired with a 390-channel magnetic tape multiplex system.

## **General Facility Specifications**

### **SONIC FATIGUE LABORATORY**

**LOCATION:** Building 49

**POINT OF CONTACT:** Chief, Structures and Mechanics  
Division, Code ES, (713) 483.2876

**STATUS:** Active

**YEAR BUILT:** 1973

**INITIAL COST:** \$1,300k

**REPLACEMENT COST:** \$4,500k

**USE:** The Sonic Fatigue Laboratory has capability to perform tests on structural panels and segments to simulate rocket-launch-induced and aerodynamically-induced acoustic noise environments. The following chambers are available for sonic fatigue testing: the primary reverberant test chamber can accommodate panels up to six meters in the modular wall and three-dimensional segments within the chamber and test levels of 166 decibels can be imposed on a test article; and the progressive wave tube can accommodate panels up to 1.8 by 3.4 meters and impose levels to 169 decibels. Excitation is normally provided by eight high-frequency or four low-frequency air modulators. A nine-thousand-kilogram bridge crane is available to lift and position specimens and fixtures.

**DESCRIPTION:** The Sonic Fatigue Laboratory can be used to test structural panels and segments to simulate rocket-launch-

induced and aerodynamically-induced acoustic noise environments. The primary test equipment consists of a medium-sized reverberant test chamber (1160 square meters) that can accommodate panels up to 4.6 to 6.1 meters in the modular wall and three-dimensional segments within the chamber. Test levels to 166 decibels (re: twenty microneewtons per square meter) can be imposed on a test article. Excitation is normally provided by one twenty-hertz, one forty-hertz, two one-hundred-hertz, and eight 2 500-hertz horns. Horns are driven by appropriate low-frequency or high-frequency air modulators.

The progressive wave tube can accommodate panels up to 1.83 by 3.35 meters and impose levels to 169 decibels. Excitation is provided by eight high-frequency or four low-frequency air modulators. Up to 198 measurements of sound, vibration, or strain can be recorded during laboratory operation.

Test conditions are controlled through the use of the same automatic equipment employed in the Spacecraft Acoustic Laboratory. Air modulators for both the Sonic Fatigue Laboratory and progressive wave tube are also driven by the same solid-state power amplifiers and air supply used in the Spacecraft Acoustic Laboratory.

A nine-thousand-kilogram bridge crane is available to lift and position test specimens and fixtures. An extension to the Spacecraft Acoustic Laboratory air manifold is used to distribute

compressed air to the air modulators mounted on either the chamber or the progressive wave tube.

#### General Characteristics

- Chamber dimensions: 12.2 by 5.8 by 4.9 meters
- Preparation area: 14.3 by 6.1 by 7.6 meters
- Chamber test panels: 6.1 meters wide by 4.6 meters high
- Access
  - Sliding door, 6.1 meters wide by 7.3 meters high
  - General Vibration Laboratory: Sliding door, 6.1 meters wide by 5.8 meters high
- Hoist: Nine-thousand-kilogram bridge crane (9.1-meter hook height)

#### Acoustic Systems

- Modular output
  - Thirty thousand acoustic watts (< five hundred hertz)
  - Ten thousand acoustic watts (< sixteen hundred hertz)
- Horns (lower cutoff): 20, 40, 50, 80, 100, 250, and 400 hertz
- Chamber level (overall): 166 decibels (twenty microneutons per square meter)
- Progressive wave tube level (overall): 169 decibels (twenty microneutons per square meter), four Wyle Acoustic Sources, Model 3000

DATA ACQUISITION: Data are acquired with a 390-channel magnetic tape multiplex system.

#### Compressed Air Systems

- Compressor 1: 764 cubic meters per minute at 206 843 newtons per square meter gauge
- Compressor 2: 679 cubic meters per minute at 206 843 newtons per square meter gauge
- Compressor 3: 85 cubic meters per minute at 206 843 newtons per square meter gauge

## **General Facility Specifications**

### **SPACECRAFT VIBRATION LABORATORY**

**LOCATION:** Building 49

**POINT OF CONTACT:** Chief, Structures and Mechanics Division, Code ES, (713) 483-2876

**STATUS:** Active

**YEAR BUILT:** 1965

**INITIAL COST:** \$3,104K

**REPLACEMENT COST:** \$7,500K

High-force testing can employ up to eight 44 480-newton shakers. Low-force testing employs various arrangements of shakers using the facility inventory of two 6672-newton shakers or two 667-newton shakers. High-force testing verifies the environmental adequacy of the test vehicle. Low-force testing determines the natural vibration characteristics (modes) of the vehicle including modal frequencies, deflection shapes, and damping values. The 44 480-newton shakers, driven by three 175-kilowatt power amplifiers, have a 3.81-centimeter diameter rod instead of a table-top armature to enable efficient coupling of energy to the test vehicle. Sine and random controls allow flexible operation of the shaker forces.

**USE:** The Spacecraft Vibration Laboratory has capability of inducing high-force vibrations on large test articles such as complete spacecraft. It can simulate vibrations produced by large boosters for spacecraft launch environment qualification tests. The laboratory is equipped to perform high-force, environmental-level vibration testing or to provide low-force, distributed-input modal excitation by exciting the test article with electrodynamic shakers.

**DESCRIPTION:** This laboratory is equipped to perform high-force, environmental-level vibration testing or to provide low-force, distributed-input modal excitation by exciting the test article with electrodynamic shakers. Operational onboard systems can be included in the test vehicle.

A 68 000-kilogram, fixed-point hoist and an eighteen-thousand-kilogram bridge crane with both eighteen-thousand- and nine-thousand-kilogram trolleys are available to lift and position test vehicles, fixtures, and work platforms. A 3600-kilogram-capacity elevator services the platforms.

Operation and control equipment is located within or adjacent to the main control room and includes three 175-kilowatt power amplifiers to drive the large shakers, twenty-four two-kilowatt power amplifiers to drive the small shakers, and instruments to provide either random or sinusoidal control of the shaker outputs. Minicomputers perform various functions related to controlling test conditions or acquiring data. A signal conditioning and recording capability (348 channels) is available for force, acceleration, or strain measurements.

**General Characteristics**

- Laboratory dimensions: 11.3 by 14.3 by 28.3 meters
- Platform elevations: 4.6, 7.6, 10.7, 13.7, 16.8, 19.8, 22.9, and 25.9 meters
- Access: Sliding door, 9.1 meters wide by 12.2 meters high
- Hoist: 68 000-kilogram fixed hoist and nine-hundred- and eighteen-thousand-kilogram trolleys on bridge crane
- Elevator: Semiautomatic with 3600-kilogram capacity

**Suspension Systems**

- Operating air pressure: 482 632 newtons per square meter gauge
  - Resonance frequency
    - Vertical translation: 1.1 hertz
    - Horizontal translation: 0.3 hertz
  - Damping ratio: Less than one percent
  - Stability ratio: 4.6:1
- Vibration System**
- Thruster force output: 44 500 newtons, continuous
  - Frequency range: five to 2.5 kilohertz
  - Displacement: 2.54-centimeters double amplitude
  - Maximum calculated force: 36 280 kilograms (eight thrusters)
- Pneumatic bearings: Bellows air springs underneath
  - Degrees of freedom: six
  - Number of springs: four
  - Total supported weight: 35 000 kilograms

## Chapter 8

### SYSTEMS ENGINEERING DIVISION (ET)

#### Contents

FACILITY	PAGE	Overview
Systems Engineering Simulator Image Generators and Display Systems .....	8-2	The Systems Engineering Division is responsible for both the development of integrated system-level requirements and the conceptual definition of systems and missions for new and advanced space systems through the program definition phases; for integrated system-level engineering and integration in support of space systems development during the design, development, test, and evaluation program phases; and for engineering analysis and technical synthesis in support of cargo integration into space transportation systems and space platforms. The Systems Engineering Division is also responsible for design, development, verification, and operations of a high fidelity, man-in-the-loop, real-time simulation of space system flight dynamics for use in design, development, and verification of space systems. It is responsible for the development of operations procedures and flight crew training for selected functions.
Systems Engineering Simulator Shuttle Ascent/Entry/Abort Simulation .....	8-3	
Systems Engineering Simulator On-Orbit Elements Simulation .....	8-4	
Systems Engineering Division Computer Laboratory .....	8-6	

## General Facility Specifications

### SYSTEMS ENGINEERING SIMULATOR IMAGE GENERATORS AND DISPLAY SYSTEMS

LOCATION: Buildings 16 and 16A

POINT OF CONTACT: Liz Duffy, Code ET5, (713) 483-1543

STATUS: Active

YEAR BUILT: 1966

INITIAL COST: Initial cost is not possible to determine; generations of computer hardware have been procured, designed, and excessed during the life of this facility.

REPLACEMENT COST: \$20,000k (rough order of magnitude)

USE: The image generators and display systems used in the Systems Engineering Simulator provide out-the-window and closed circuit television pictures to the Systems Engineering Simulator crew stations in real time. These images are critical to the realistic simulation of spaceflight. The image generators provide the crew station member with views out of the windows and views from simulated closed circuit television cameras. These views can be used to evaluate the response of various systems being simulated, such as the Shuttle or Space Station Remote Manipulator systems or the orbiter control system.

DESCRIPTION: The Systems Engineering Simulator image generators consist of an Evans and Sutherland CT3, a POLY 2000e, and an Evans and Sutherland CT6. The CT3 is the

oldest system and is capable of providing two channels of visual simulation. The POLY 2000e was procured in 1985. It is microprocessor-based and has three channels with limited fidelity. Because of word-length limitations the POLY 2000e cannot be used to support fine detail work such as Remote Manipulator System capture work. The CT6 is the largest system and can generate six independent images; it includes hundreds of stars and a moving cloud cover on Earth. The CT6 can texture objects to give them an appearance of roughness or superimpose photographic data on the simulated surfaces. The Systems Engineering Simulator display systems consist of nine-inch, closed-circuit television monitors and pancake or wide-angle columned display systems for cockpit windows. The Systems Engineering Simulator has a dome display system and extension for Building 16 to house the dome on contract. These facilities are scheduled to be on-line by early FY 1993. The dome will be used for Space Station Freedom assembly and cupola operations. The image generators and display systems are connected through a video distribution rack to provide maximum flexibility, permitting every image generator access to multiple crew stations.

DATA ACQUISITION: The visuals can be recorded from the scene generator outputs in both phase alternating line and National Television Standards Committee formats.

## **General Facility Specifications**

### **SYSTEMS ENGINEERING SIMULATOR SHUTTLE ASCENT/ENTRY/ABORT SIMULATION**

**LOCATION:** Buildings 16 and 16A

**POINT OF CONTACT:** Carl Martin, Code ET5, (713) 483-1559

**STATUS:** Active

**YEAR BUILT:** 1968, Evolved from Apollo Simulation

**INITIAL COST:** Initial cost is not possible to determine; generations of computer hardware have been procured, designed, and excessed during the life of this facility.

**REPLACEMENT COST:** \$5,000 (rough order of magnitude)

**USE:** The Systems Engineering Simulator Ascent/Entry/Abort Simulation provides the Space Shuttle program with a functional real-time flight simulator with a medium-fidelity crew station. The facility is used to design and test Shuttle guidance, navigation, and control algorithms prior to the creation and changing of actual ascent, entry, and abort flight software. Astronauts and engineering test pilots use the crew station to "fly" the system and evaluate proposed software changes. All Shuttle commanders and pilots are trained in the Systems Engineering Simulator for ascent and abort situations. In addition to real-time activities, the facility is used to run non-real-time batch simulations of Shuttle flight operations. A Monte Carlo capability has been added to the entry part of the simulation.

**DESCRIPTION:** The Systems Engineering Simulator Ascent/Entry/Abort Simulation consists of a Cyber 962 mainframe computer system, CDC 4000 processors, specialized communication interfaces, analog strip chart recorders, and a Shuttle Flight Deck Crew Station. The Cyber 962 uses the NOS/VE operating system, with a specialized RTP/VE real-time software extension to NOS/VE. The RTP/VE is capable of scheduling multiple real-time tasks and handling real-time input and output to disk and external devices. The Cyber 962 and CDC 4360 hosts reside in Building 16, Room 290. Customized data interfaces connect the Cyber 962 with the strip charts and crew station. A Systems Engineering Laboratories 75 series computer is used to buffer graphics data and crew station input and output. A Poly 2000 image generator is used to provide the commander with an out-the-window display of the runway and airfield environment during approach and landing operations.

**DATA ACQUISITION:** The Systems Engineering Simulator Ascent/Entry/Abort Simulation is capable of recording a maximum of 256 user specified simulation parameters to disk and nine-track magnetic tape at a maximum data rate of twenty-five hertz. An additional thirty-two user specified simulation parameters can be recorded on strip charts at a fixed data rate of twenty-five hertz. The Monte Carlo version of the batch simulation records various snapshot and minimum or maximum data in the Oracle Database Management System.

## General Facility Specifications

### SYSTEMS ENGINEERING SIMULATOR ON-ORBIT ELEMENTS SIMULATION

LOCATION: Buildings 16 and 16A

POINT OF CONTACT: James Newsome, Code ET5,  
(713) 483-1542

STATUS: Active

YEAR BUILT: 1962, Evolved from Gemini Simulation

INITIAL COST: Initial cost is not possible to determine; generations of computer hardware have been procured, designed, and excessed during the life of this facility.

REPLACEMENT COST: \$10,000k (rough order of magnitude)

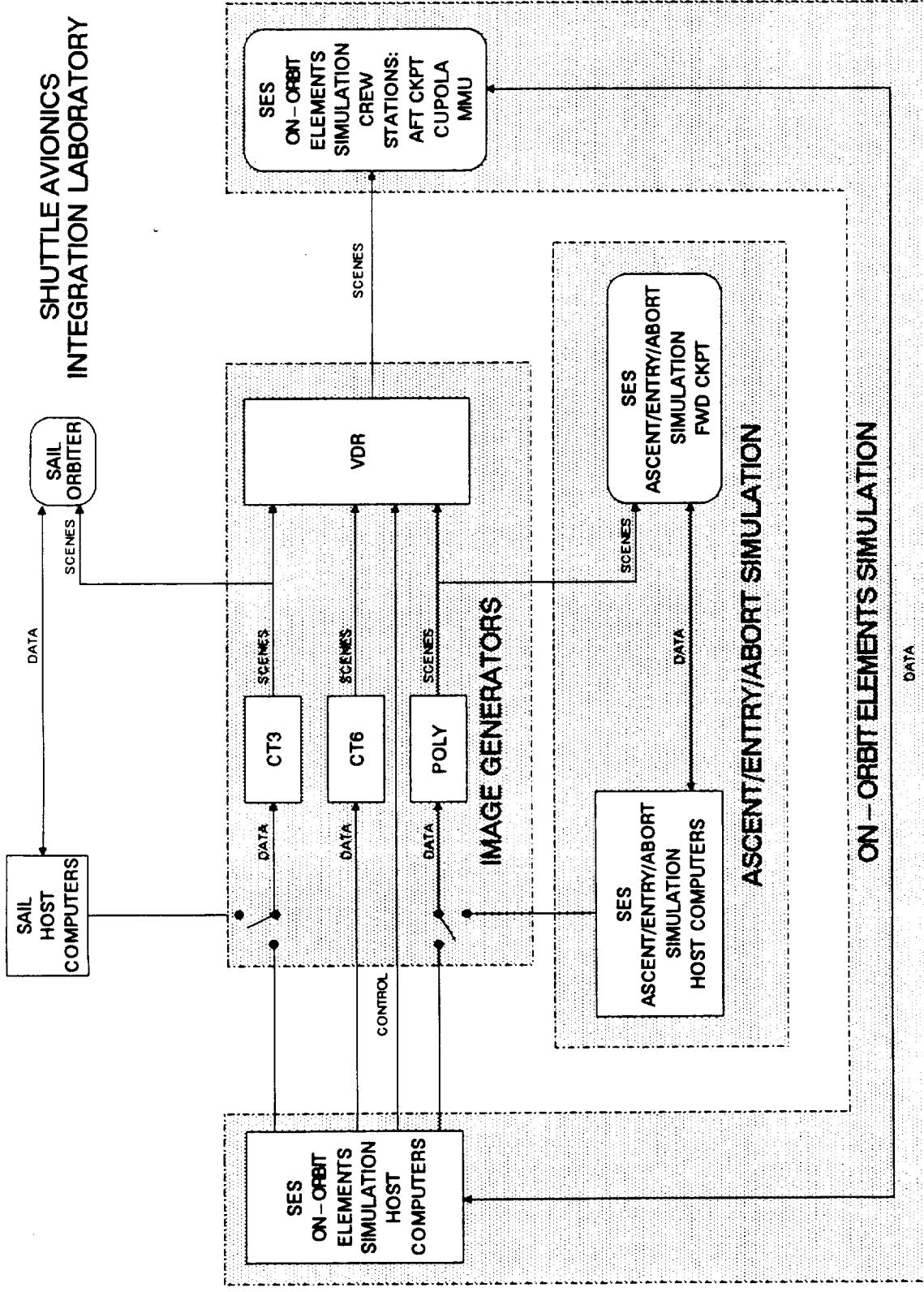
USE: The Systems Engineering Simulator On-Orbit Elements Simulation is used to test advanced concepts of on-orbit Shuttle and Space Station Freedom operations; develop, validate, and train crews in flight procedures; and provide an interactive real-time Shuttle, Space Station, and Manned Maneuvering Unit facility. The On-Orbit Elements Simulation operates on a three-shift, seven-days-per-week schedule. The on-orbit simulation is used for Remote Manipulator System training for each Shuttle crew. Systems Engineering Simulator math models are available for use by the Shuttle Avionics Integration Laboratory.

DESCRIPTION: The Systems Engineering Simulator On-Orbit Elements Simulation is hosted on multiple Encore 87 super-minicomputers residing in Building 16, Room 100A. Math

models that functionally represent the flight control software and environment are distributed within the Encore 87s, and the computers are interconnected with a proprietary high speed, shared memory system. The simulation operates with a forty millisecond frame time, exactly matching the Shuttle flight system. The simulation can support simultaneous and independent Shuttle and Space Station operations or by operating together can simulate interactive two-crew station operations such as berthing or payload transfers. There are three-crew stations connected to the On-Orbit Elements Simulation: the Shuttle Aft Flight Deck, the Space Station cupola, and the Manned Maneuvering Unit station. The simulation is enhanced by the use of multiple image generators which provide simulated out-the-window scenes and closed-circuit television pictures to the crew stations.

DATA ACQUISITION: The Systems Engineering Simulator On-Orbit Elements Simulation is capable of recording a maximum of eight thousand words of user specified simulation parameters to nine-track magnetic tape at a maximum data rate of twenty-five hertz. Extensive data reduction and plotting is available. An additional thirty-two words of user specified simulation parameters can be recorded on strip charts at a fixed rate of twenty-five hertz. Up to two thousand words can be printed during real time at a maximum rate of 0.5 hertz with 0.1 hertz being more commonly used. Vehicle state data and other predetermined parameters can be printed at simulation initialization and termination.

## SYSTEMS ENGINEERING SIMULATOR FUNCTIONAL LAYOUT



## General Facility Specifications

### SYSTEMS ENGINEERING DIVISION COMPUTER LABORATORY

LOCATION: Building 17, Rooms 113 and 2037

POINT OF CONTACT: Rey Rivera, Code ET14, (713) 483-8081

STATUS: Active

YEAR BUILT: 1990

INITIAL COST: Not available.

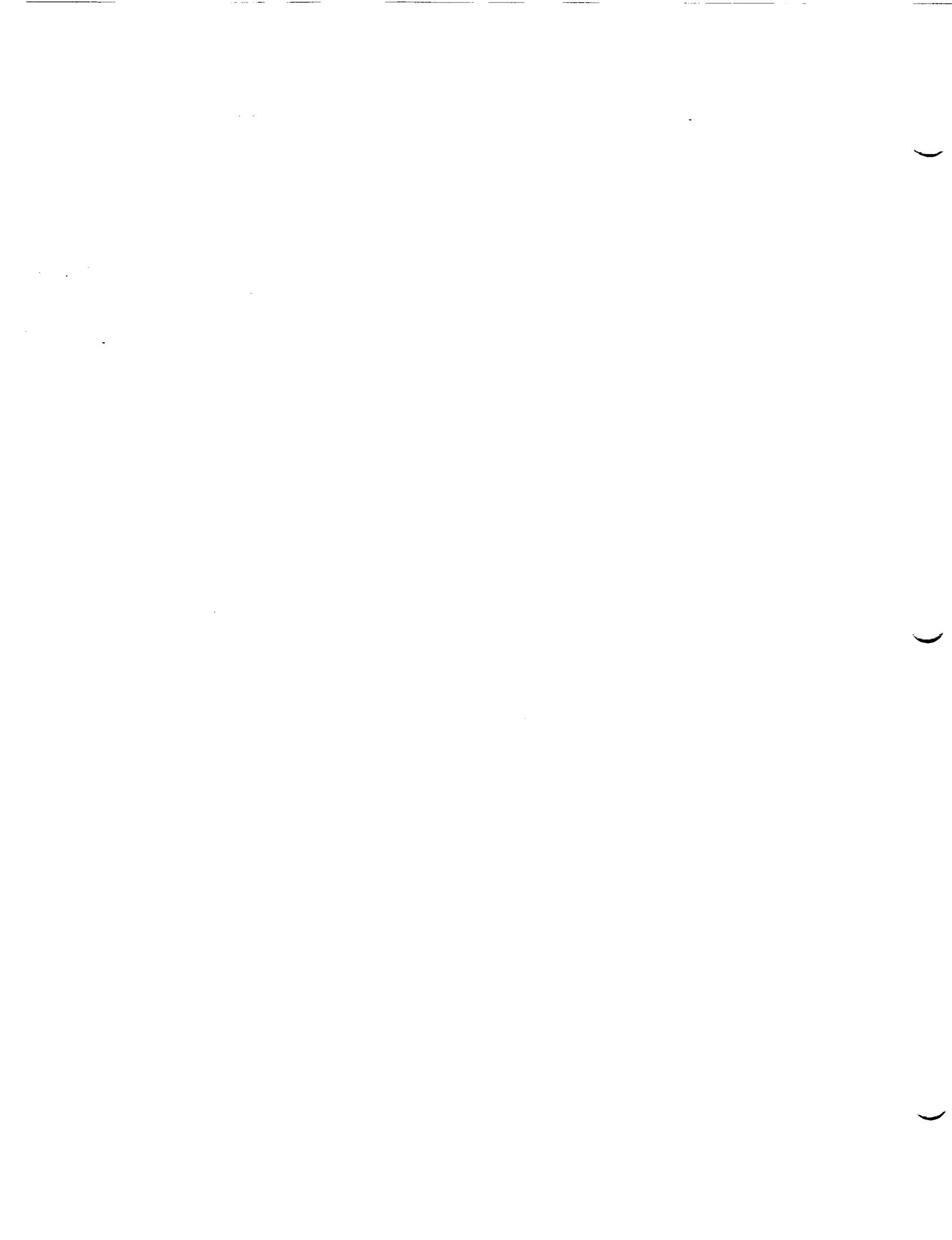
REPLACEMENT COST: Not available.

USE: Facilities in the Systems Engineering Division Computer Laboratory are used to perform vehicle sizing, subsystem trades, and configuration analyses. The end product is typically a vehicle design, subsystem definition, mass property estimate, and so on. State-of-the-art hypermedia technology is also being applied to the development of graphics data bases and animations of vehicles and missions. The Computer Laboratory is used in support of trajectory design and analysis. Data is generated for Lunar and Mars Exploration Program Office studies to assess the implications of specific lunar site locations and surface stay time requirements for lunar mission design. Other studies being performed include the Lunar and Mars parking orbit selection study and the Space-to-Ground System Ku-band antenna communications coverage for the man-tended capability configuration. The three Silicon Graphics workstations in the Computer Laboratory are used to provide modern 3-D graphics and animation. Complex orbital motions such as

the shape of the orbit, inclination, apsidal rotation, and nodal regression are easily visualized. The Computer Laboratory is used to support software maintenance and modification of existing software, and development of new software tools. The primary programming languages include FORTRAN, C, and Ada. Programs supported by the Computer Laboratory include the Assured Crew Return Vehicle, the Common Lunar Lander, Exploration Programs, Advanced Manned Transportation Systems, the Space Station, the Shuttle, and Lifesat.

DESCRIPTION: The System Engineering Division Computer Laboratory consists of minicomputers, Apples, IBM compatible personal computers, printers, terminals, network equipment, and file servers. There is a technician's work room located in the Computer Laboratory which is used to perform network backups for all ET Division Apple computers in Building 17, to store backup tapes, to perform diagnostics and repair equipment, and to perform evaluation of new computers and software. Hewlett Packard minicomputers are mainly used by Flight Analysis System users. The Sun computers are multiuser machines, as well as the Apples, IBM compatible personal computers, and IRIS minicomputers. The IRIS has special 3-D graphics and animation software. The Textronix terminals are specialized graphics terminals used for the IDEAS computer-aided design package. The Codonics terminals are used for network connectivity. The ET Local Area Network, or ET LAN, is connected to JSC Engineering and Science Network, or JESNET, through a router located in the Computer Laboratory.

DATA ACQUISITION: The Systems Engineering Division Computer Laboratory has three Textronics color printers connected to the IRISSes and the Apple network. Every computer has access to disk storage, tape drives, and printers for data output.



## **Appendix**

### **LIST OF FACILITIES BY BUILDING NUMBER**

#### **BUILDING 7**

**Advanced Life Support Systems Development and Test Complex (EC)**

**Advanced Materials Laboratory (EC)**

**Chamber Operations, Lock Observers, and Personnel Equipment Shop (EC)**

**Chemistry Laboratories (EC)**

**Data Acquisition, Recording, Display, and Computer Complex (EC)**

**Eight-Foot Chamber Life Support Systems Canned-Man Test Complex (EC)**

**Electrical Fabrication, Electronic, and Instrumentation Shops (EC)**

**Eleven-Foot Chamber Manned Test Complex (EC)**

**Impact Test Facility (EC)**

**Instrumentation Calibration and Electronic Repair Laboratory (EC)**

**Mechanical Shops (EC)**

**Shuttle Thermal and ETA Test and Man-Rated Training Complex (EC)**

**Soft Goods Fabrication Laboratory (EC)**

**Special Chambers Complex (EC)**

#### **BUILDING 7B**

**Regenerative Life Support System Test Bed (Variable Pressure Growth Chamber, Ambient Pressure Growth Chamber)**

#### **BUILDING 9NE**

**Automation and Robotics Division Laboratory Support (ER)**

**Dexterous Robotics Laboratory (ER)**

**Electronics Development Laboratory (ER)**

**Manipulator Development Facility (ER)**

**Mobile Robotics Laboratory (ER)**

**Robotic Sensor Integration Laboratory (ER)**

**Robotic Systems Evaluation Laboratory (ER)**

**Space Systems Automated Integration and Assembly Facility (ER)**

**Telepresence Laboratory (ER)**

#### **BUILDING 13**

**Electro-mechanical Systems Laboratory (ES)**

**Materials Technology Laboratory (ES)**

**Atomic Oxygen Facility (ES)**

**Chemical Analysis Laboratory (ES)**

**Electron Microscopy Laboratory (ES)**

**Mechanical and Physical Testing Laboratory (ES)**

Metallurgical Laboratory (ES)  
Nondestructive Testing Laboratory (ES)  
Rubber Laboratory (ES)  
Thermal Analysis Laboratory (ES)  
Small Radiant Heating Test Facility (ES)  
Structures Test Laboratory (ES)

**BUILDING 16**

Computing Facility (EK)  
Displays and Controls Laboratory (EK)  
Electrical Power Systems Laboratory (EP)  
Real-Time Systems Engineering Laboratory (EK)  
Multiplexer/Demultiplexer and Orbiter Data Bus Test Laboratory (EK)  
Shuttle Avionics Integration Laboratory (EK)  
Systems Engineering Simulator Image Generators and Display Systems (ET)  
Systems Engineering Simulator Shuttle Ascent/Entry/Abort Simulation (ET)  
Systems Engineering Simulator On-Orbit Elements Simulation (ET)

**BUILDING 14**

Anechoic Chamber (EE)  
Communication Systems Development Laboratory (EE)  
Electromagnetic Compatibility and Electromagnetic Interference Test Laboratory (EE)  
Government-Furnished Equipment Flight Hardware Development and Processing Facility (EE)  
Global Positioning System Laboratory (EE)  
Hybrid Vision Laboratory (EE)  
Image-Based Tracking Laboratory (EE)  
Microwave Design Laboratory (EE)  
Microwave Integrated Circuit Facility (EE)  
Optical Tracking and Communications Laboratory (EE)  
Outdoor Antenna Range Facility (EE)  
Radar Laboratory (EE)  
Precision Six-Degrees-of-Freedom Test Facility (EE)

**BUILDING 16A**  
Electro-Optics Laboratory and Rooftop Tracking Laboratory (EG)  
Flight Tape Recorder Laboratory (EK)  
Inertial Components Laboratory (EG)  
Inertial Systems Laboratory (EG)  
Instrumentation Laboratory (EK)  
JSC Avionics Engineering Laboratory (EK)  
Microprocessor Laboratory (EK)  
Modular Auxiliary Data System Instrumentation Laboratory (EK)

<b>Space Station 1553 Local Bus Test Bench (EK)</b>	<b><u>BUILDING 34</u></b>
Time Generation System Testbed (EK)	Advanced EVA Mobility Unit Development Laboratory (EC)
<b><u>BUILDING 17</u></b>	Extravehicular Activity Robotics Laboratory (EC)
<b><u>BUILDING 18</u></b>	
Radar Boresight Facility (EE)	<b><u>BUILDING 44</u></b>
Radar, Nav aids, and GPS Facility (EE)	Advanced Audio Development Laboratory (EE)
	Advanced Voice Processing Laboratory (EE)
	Communication Systems Simulation Laboratory (EE)
	Communications Software Development Laboratory (EE)
	Electrical-Acoustical Laboratory (EE)
	Electronic Systems Test Laboratory (EE)
	Flight Equipment Assembly Area (EE)
	Signal Processing Laboratory (EE)
	Television Systems Laboratory (EE)
	Text and Graphics Laboratory (EE)
	Video Cassette Recorder System Laboratory (EE)
<b><u>BUILDING 32</u></b>	
Chamber A High Vacuum/Thermal Man-Rated Test Complex (EC)	<b><u>BUILDING 46</u></b>
Chamber B High Vacuum/Thermal Man-Rated with Solar Test Complex (EC)	Software Development Facility (EK)
Data Acquisition, Display, and Recording Systems (VAX/NEFF) (EC)	
Heat Pipe and Thermal Test Complex (EC)	<b><u>BUILDING 49</u></b>
Intelligent Systems Laboratory (ER)	Vibration and Acoustic Test Facility (ES)
Laboratory Support (ER)	General Vibration Laboratory (ES)
	Modal Operations Laboratory (ES)
	Sonic Fatigue Laboratory (ES)
<b><u>BUILDING 32A</u></b>	
Integrated Graphics Operations and Analysis Laboratory (ER)	
<b><u>BUILDING 33</u></b>	
Data Acquisition System (VAX/NEFF) (EC)	
Special Chambers Complex (EC)	

**Spacecraft Acoustic Laboratory (ES)**

**Spacecraft Vibration Laboratory (ES)**

**BUILDING 222**

**Pyrotechnics Test Facility (EP)**

**BUILDING 241**

**Atmospheric Re-entry Materials and Structures Evaluation Facility (ES)**

**BUILDING 260**

**Hybrid Regenerative Wastewater Recovery Lab (EC)**

**BUILDING 350**

**Radiant Heating Test Facility (ES)**

**BUILDING 351**

**Thermochemical Test Area (EP)**

**BUILDING NUMBER TO-BE-ASSIGNED**

**High-temperature Superconductivity Laboratory**

**Thermal Vacuum Test Facility (EP)**

**BUILDING 352**

**Propulsion Test Facility (EP)**

**BUILDING 353**

**Fluid Systems Test Facility (EP)**

**BUILDING 354**

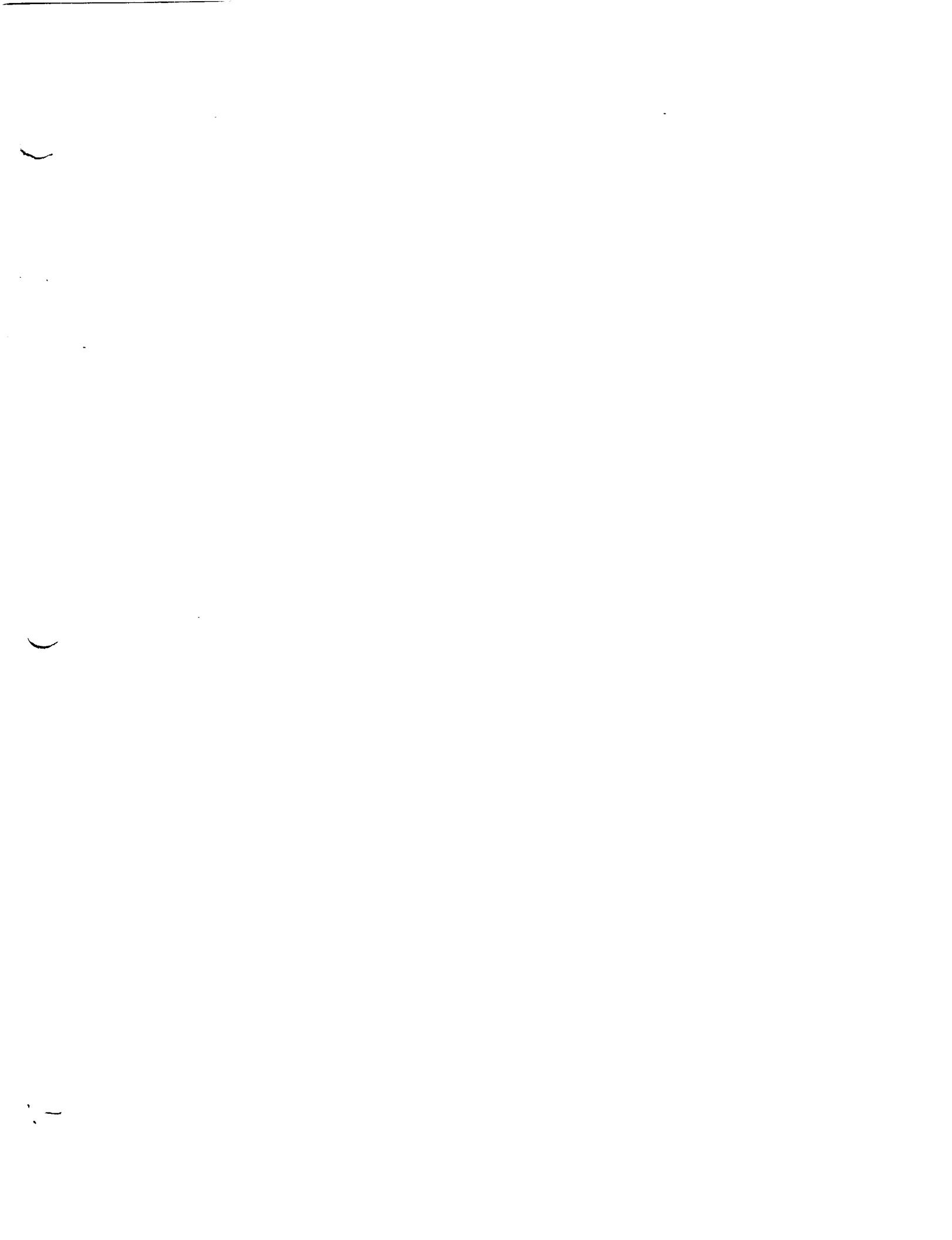
**Power Systems Test Facility (EP)**

**BUILDING 356**

**Fluid Systems Test Facility (EP)**

**BUILDING 450**

**Radar Boresight Facility and Boresight Range (EE)**



EA131-93-013

Distribution:

AA/A. Cohen  
AB/P. J. Weltz  
AC/D. A. Nebrig  
AT/J. P. Loftus  
BA/W. R. Kelly  
CA/D. R. Puddy  
DA/E. F. Kranz  
EA/M. Engert  
EA/H. O. Pohl  
EA/R. C. Ried  
EA131/C. Chullen  
EA131J. E. Maloy (15 copies)  
EA131/R. D. Schwartz  
EA7/D. J. Westfall  
EC/W. E. Ellis (3 copies)  
EE/C. K. Land (3 copies)  
EG/K. J. Cox (3 copies)  
EK/P. E. Sollock (3 copies)  
EP/C. A. Vaughan (3 copies)  
ER/W. W. Guy (3 copies)  
ES/D. C. Wade (3 copies)  
ET/C. A. Graves, Jr. (3 copies)  
PA/R. L. Berry  
GA/L. S. Nicholson  
IA/W. J. Huffstetler  
IC4/D. C. Glenn  
JA/K. B. Gilbreath  
JM2/Technical Library (2 copies)  
KA/J. W. Aaron  
NA/C. S. Harlan  
SA/C. L. Huntoon  
TA/C. H. Lambert, Jr.  
VA/D. M. Germany  
XA/D. Cooke  
YA/J. H. Greene

ARC/202-3/Technical Library  
DFRF/D-2151/Technical Library  
GSFC/252/Technical Library  
JPL/111-113/Technical Library  
KSC/867-3613/Technical Library  
LaRC/MC 185/Technical Library  
LaRC/MC 106/D. R. Branscome  
LeRC/60-3/Technical Library  
MSFC/4200/Technical Library  
Stennis Space Center/Technical Library  
LESC, C24/M. M. Miller (12 copies)